THE ROMANCE OF OUR WONDERFUL WORLD

By P. J. RISDON

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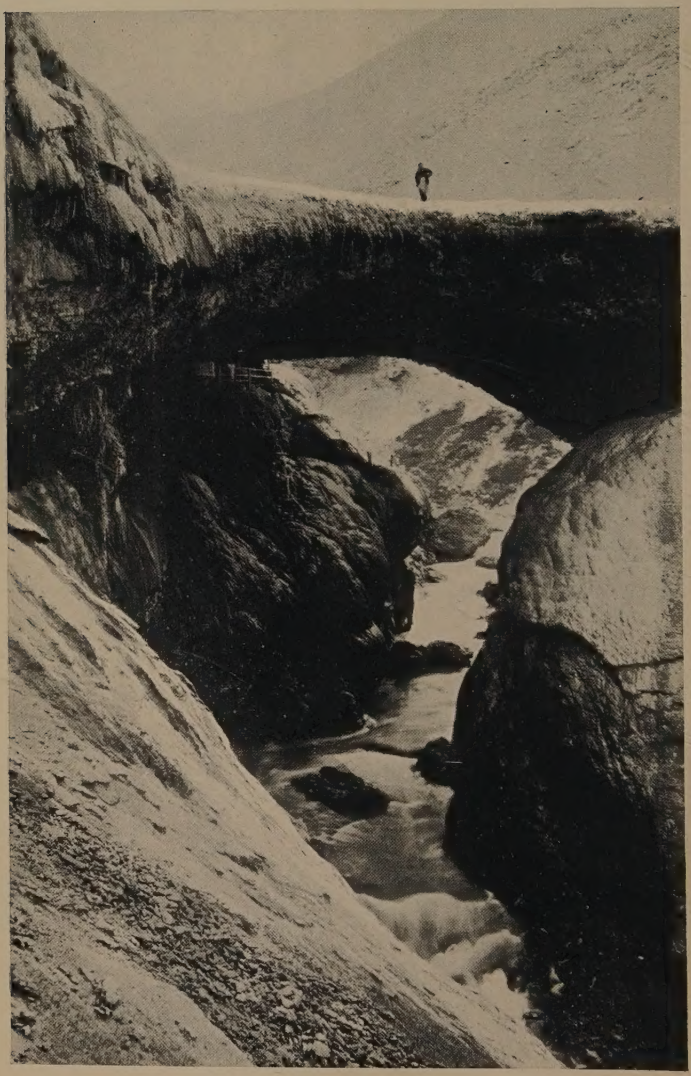
THE ROMANCE OF OUR WONDERFUL WORLD



A Natural Bridge of Rock

This is an illustration of how, having encountered a mass of rock not easily worn away, a river scoured its way beneath it, leaving it in the form of a great arch, known as the Inca Bridge.

By courtesy of the Peruvian Corporation.

THE ROMANCE OF OUR WONDERFUL WORLD

THE STORY SIMPLY TOLD OF THE EARTH'S BEGINNING, ITS MANIFOLD WONDERS & THE TREMENDOUS FORCES WHICH HAVE TRANSFORMED A SPHERE OF FLAMING GASES INTO THE BEAUTIFUL WORLD OF TO-DAY

BY

P. J. RISDON, F.R.S.A.

AUTHOR OF "WIRELESS REALLY EXPLAINED," &c., &c., &c.

WITH 34 ILLUSTRATIONS

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TO THE GREAT SCIENTISTS,

PAST AND PRESENT,

WHOSE RESEARCHES AND DISCOVERIES

HAVE MADE ITS WRITING POSSIBLE,

THIS BOOK IS DEDICATED

"Reasoning can conjure up beside the present picture far vistas of what preceded it and of what is yet to come."

Dr. Percival Lowell.

PREFACE

IN the present volume, an endeavour has been made to present the story of the Globe on which we live from its first condition of chaos, and some of its natural wonders, that will serve both as a bird's-eye view, and as a key to the storehouse of knowledge that needs but to be unlocked to disclose unlimited treasure. So far as we are aware, no attempt has as yet been made, on a systematic basis, to embrace between two covers such an outline; with the consequence that the average person, with no time or inclination for studying technical works on astronomy, geology, chemistry and physics generally, has hitherto had to fall back upon the necessarily fragmentary treatment of science in magazines and newspapers, in which there is usually a tendency to lend colour to the latest startling "theory" about Mars, or the formation of lunar craters.

Nevertheless, there is a large number of persons, to whom such matters are at present a mystery, ready and anxious to learn something about them, providing that the subject-matter be collated in a palatable form, and it is earnestly hoped that to such the present work will prove both interesting and instructive.

PREFACE

An erroneous impression has gained ground that "Babels" in scientific circles prevent a general concensus of opinion on any subject, and that recent discoveries have revolutionized all preconceived ideas and knowledge; but such is not the case. If the theory of Relativity has exploded the old notion of an elastic-solid ether, no harm is done; the ether theory is merely a hypothesis, and was never accepted without important reservations. Again, whereas it used to be supposed that an atom was the smallest conceivable unit, it is now known that it consists of a minute solar system of protons and electrons. Yet this has not revolutionized chemistry: it simply means that human knowledge has been extended.

It will readily be appreciated that, in a single volume, it is impossible to deal with all modern theories that have been advanced. For example, the Sun's energy has been ascribed to radio-activity; it is believed by some that the atoms of all matter have been evolved from atoms of hydrogen; and there is a theory that water and air escape from a planet into space as the result of molecular energy exercised near the confines of its atmosphere.

To many readers much that follows will come as a revelation, and the incredulous may contend that human experience has not covered the ground. Such criticisms may be anticipated by the reminder, first that almost everything we call knowledge may be, and often is, a matter of dispute; and secondly, that

by far the greater part of human knowledge is attained by deduction: this applies to many things that we accept without proof and without demur. Those who profess to believe nothing save what is perceptible to their physical senses, do so as the result of ignorance or prejudice. No one has seen or heard God, yet, independently of the Bible, we are compelled at every turn and by everything we witness in Nature, to acknowledge a Supreme Deity.

Although not written in a religious sense, in the ordinary acceptation of the term, it will be found, reading between the lines, that this book is in part but a more detailed account of events related and foretold in the Bible, so impressively and in so few words. The prophecy that the World will be destroyed by fire is borne out by what astronomers believe that they have seen take place in the firmament: the collision in space of dark bodies—dead suns and worlds—and their return to a state of fiery nebulæ.

The story of the World may be likened to a description of a thrilling transformation scene that might well rouse the emotion of the most blasé amongst us. Space is the stage, and in the coldness and solitude of space, the scene begins and ends. And in this great drama it is given to those who will to perceive, if but dimly, the marvellous harmony of the vast forces of Nature in the creation from elements of a globe with a solid crust, a beautiful World, and finally in its dissipation again in space as gaseous

elements and meteoric matter—the destruction of the mighty works of Creation.

There are not wanting those who think it presumptuous and wrong to forecast events in the Universe. Certainly no sane person would atempt to lay down the law about them. Yet surely, since we are endowed with reasoning intelligence, it cannot be wrong humbly to enquire, and endeavour to penetrate the veil that obscures the Future ?

This, then, is our object : to picture how a plastic shell formed round a globe of incandescent matter in space ; how it thickened and cooled ; the division of land and water ; the majestically slow upheaval of mountain ranges ; the first lowly forms of life—blind creatures giving place to those with eyes, as the Sun's rays penetrated the veil of water vapour ; ever-changing conditions favouring the development of species ; how Nature ploughed, harrowed, sifted and watered the land in preparation for higher forms of life ; the gradual dissipation of the Earth's internal heat ; the dying out of every kind of life ; and of the ultimate destruction of our wonderful World, and the scattering forth of its remains in space.

If, in the telling, the Author succeeds in arousing a tithe of the interest the subject merits, he will feel well rewarded.

The writer's thanks are due to Mr. W. Hemingway for valuable assistance in the correction of proofs.

P. J. R.

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ROMANCE OF OUR WONDERFUL WORLD

CHAPTER I

SPACE—GRAVITY—THE BEGINNING OF THE WORLD

IF we would gain real knowledge of the World on which we live, we must begin at the beginning. And to do so means that we must make an excursion (in imagination) into realms which only astronomers usually explore. They are the realms of space. And so mysterious are those realms, so far more wonderful than we could have supposed without the help of our astral observers, that it is worth while to try to form some idea of what is meant by space.

That is not altogether an easy thing to do. There is a story of an Irishman who, asked to define space, replied, "Space is a thing that can't be explained—so I'll just describe it to you. It's like a big box with the top and the bottom, and all the sides knocked out of it. And the nearer you get to the end of it, the farther you are away from it." That is one way of describing space. There is no top or bottom or

side to it, and there is no beginning and no end. But let us try to bring it home a little more clearly.

Suppose that you could be transported back through untold ages, into space, before the World existed. Your first act would almost certainly be to stretch out your arms and legs—to try to touch something. When you found that you could feel nothing, you would think it very strange—especially not knowing whether you were on your head or your heels, on your back or on your stomach. You would be unable to walk, crawl or swim; for there would be nothing to walk upon, or to work against. However much you moved your limbs, you would be beating or treading on nothing. If you tried to turn a somersault, you would not know whether you succeeded in doing so. You would not even know whether you were moving or at rest. *There would be no question of falling:* all the particles of which you consist would gravitate towards your own centre of gravity, providing that you were far enough removed from the attractive influence of any other body.

Of course, your position is imaginary, in more senses than one. Space, for the most part, is so intensely cold that you would instantly be frozen stiff and solid. Moreover, space is not so empty as people used to think. It contains matter and energy, and one form which that energy takes is that of matter in motion. Matter is anything that exists: it may constitute a very big thing like the World, or a very

tiny one, called an atom, that cannot be seen under the most powerful microscope, or even an electron, which is so minute that all attempts to convey an intelligible idea of its smallness must necessarily fail.

Now, all matter in space is in motion. How it was first set in motion no one knows, but astronomers have discovered the reasons for it in the wonderful consequences thereof.

After toying with a magnet and finding that it will only pick up a piece of iron or steel, one is apt to suppose that these are the only things which attract each other. But that is quite wrong.

Everything that exists, great or small, possesses an attraction for everything else, and the power and effect of this attraction depend upon the size and weight of the things, and their distance from each other. Such attraction is called gravitation. Two bodies of equal size and weight attract each other equally, and, in space, two equal masses of matter would move towards each other at the same speed. The force of this mutual attraction varies approximately inversely as the square of their distances apart. Thus, at a distance of 100,000,000 miles, the attraction is not half, but only one quarter as much as at 50,000,000 miles.

Pour a little quicksilver (mercury) on to a clean, dry, level piece of polished glass, and separate it into two portions, one portion several times as large as the other. Push the larger portion slowly towards the smaller, and you will find that, when sufficiently

near, the small pool will begin to move and will run into the larger one.

Next, divide the quicksilver into two equal parts, and push each part slowly towards the other. If this is done delicately enough, both portions will elongate and run together.

Now, scatter the quicksilver, and it will be seen that each portion is globular, like a tiny ball. The reason is, that when matter attracts matter, the particles not only meet, but *each particle tries to get to the centre of the mass.* Of course, only one can be in the centre, but all the others, in their endeavour to get there, so jostle and push and climb over each other that they actually form a globular mass. It is something like a scrum at a football match. In a real good scrum the men pack themselves together until they look almost like a ball of human beings. That is what matter is doing always and everywhere. It is known as gravitation.

If we push two of the little balls of quicksilver together, they will form another ball twice the size, again proving that all the particles have the same objective. We may add one ball after another, with the same result, until the mass begins to flatten out. That is because, mercury being fluid, the attraction of the Earth drags down the upper particles, and so forces the others outward. Even then, the pool remains circular, with quite high edges, showing that the particles are still trying to reach the centre. If the attraction of the Earth were removed, they would

again form a ball, and, in space, would retain a spherical form. If we push the edge inward with a pencil, or even if we push a pencil right through the pool, we displace the particles; but back they will work their way when the pencil is removed.

There are analogous occurrences in the plant world. For instance, particles of moisture, condensed on a leaf at the end of a hot summer's day, attract each other and, being fluid, form almost round beads of dew. Again, melted lead dropped from a height makes almost round shot, the reason being that as they fall the earth attracts every particle with equal force, consequently the particles are able to exert their mutually attractive force almost uninterruptedly and so to form little spheres which, by the time they have reached the end of the fall, have cooled and hardened. Thus the law that fluids in space in coming together assume a spherical form has been utilized for making shot for the cartridges of sporting guns.

Imagine it to be possible to bore a hole right through the centre of the Earth, and for a stone to be dropped down the hole from each end: the two stones would not fall out at opposite ends, but would meet at the centre and stay there—or rather, what remained of them would stay there. (The impossibility of such an experiment need not be enlarged upon.)

The tiny electrons previously mentioned are believed to constitute electricity as well as gases, liquids and solid matter. It has already been explained that matter in motion is a form of energy. But so

also are electricity, heat and light, which are produced by putting matter into motion, or altering or stopping its motion. If we strike two cold pieces of metal together repeatedly, they become hot. If we rub glass and silk together, electricity is generated; if we place a resistance in the path of an electric current, we produce heat and light.

Matter and energy are indestructible. If we burn a piece of wood or coal, we merely change the condition of matter: we cannot destroy it. There may be only a little ash left, but all the other constituents of the piece of coal or wood are somewhere—partly, perhaps, in the form of wandering atoms—and Nature will again make use of them in some way.

Almost every child knows that the Sun is a mass of flaming gases, and that, revolving round it at varying distances, are planets, of which the World is one. The Sun and planets together constitute what is known as a solar system. Many persons are accustomed to regard our little World as the only one in the universe—or, at least, as the only one on which human life exists. Yet, when we consider that every star is a sun, like our own Sun, it is reasonable to suppose that there must be countless other worlds on which there is life, perhaps of a higher—perhaps of a lower—order than ours.

Notwithstanding that, on a clear night, the sky appears to be thickly dotted with stars, the solar systems, of which they are the visible representatives, are separated by incalculable distances.

In addition to the movements of individual members, solar systems, as a whole, move through space relatively to each other, at a speed many hundreds of times faster than that of an express train. Consider the result of a collision between, say, our World and another, travelling at such speed: the heat generated would be so tremendous that not only would both be smashed to fragments, but those fragments would be dissipated in fiery gas, which might spread throughout billions of miles of space.

The World was once a seething ball of flame, like the Sun is now; but in the course of ages, subjected to the coldness of space, chemical action took place, and gases combined, forming a solid crust. Even now that crust is comparatively thin: it is believed to be less thick in proportion to the World's diameter than the rind of an orange is to the diameter of the orange. In ages to come the Sun also will cool, and its surface will become hard and cold. Roving about in space are such extinct suns and worlds—there may be more of them than there are stars. Sometimes they collide: it may be an end-on collision, or they may barely graze. An end-on collision would result in a nebulous cloud of fire; a glancing collision in a whirling spiral. In the course of ages the resulting gaseous matter—and such solid particles as might have escaped—would come together again by the force of gravitation. The late Sir Robert Ball explained how, as the particles of an irregular nebulous cloud gravitate together, the sum total of their motions

would result in a spiral motion of the whole, corresponding to that of the original solar system or systems from which the nebula was formed. Then, in the spiral sweep local accumulations would occur, and, in the course of ages, the fire mist would be absorbed by these accumulations which, although still gaseous, would assume a spherical form. Thus, out of the debris of old, dead suns and worlds, new solar systems arise.

In addition to the planets, circling round the Sun are belts of fragments of solid matter. More or less continuously, but more especially at certain times of the year, these belts come into contact with the outer fringe of our atmosphere, some of the fragments, many of which are of enormous size, are caught in it, and the friction of the air, due to their speed, renders them incandescent. They are popularly known as meteors or "falling stars." Most of them are consumed by heat, generated by this friction, and only reach the Earth's surface as dust.

Some, however, reach the Earth in a solid state, and are known as siderites and aerolites, examples of which may be seen in museums. To handle one may be to handle a portion of a world on which people once lived, that met with one of those fearful catastrophes in space.

The idea of gaseous matter changing to liquids and solids may seem puzzling; yet, when we consider a few of the things performed daily in chemical laboratories, it appears less of a miracle.

THE GREAT NEBULA IN THE CONSTELLATION OF ORION

From a photograph taken at the Yerkes Observatory.

A Shower of Meteors

A meteoric shower is one of the grandest of astronomical spectacles. Beginning with a display of one or two, then tens, then hundreds, it culminates in a "rain of fire." Such spectacles were witnessed in 1833, 1866, and 1872. The meteors all diverge from a common "radiant-point."

Every substance, however solid, consists either of combinations of gases or vapours, and about half of everything that exists consists of a gas called oxygen. A chemist can mix oxygen and hydrogen, and, by passing an electric spark through, or applying a light to, the mixture, produce water. It takes a large volume of the gases to make a comparatively small quantity of water: for every cubic foot of water, it would need about 2500 cubic feet of the two gases.

Conversely, by passing an electric current through water, the water can be converted into oxygen and hydrogen. Again, if sufficient heat be applied to any substance, it can be converted into gases or vapour. For instance, heat changes water to steam, and a sufficient amount of heat would convert iron, stone, or carbon into vapour.

When a solid or liquid is vapourized, the vapour occupies an immensely greater volume than the original substance ; and the converse of course holds good.

A most important point to bear in mind is that, under natural conditions, and within certain limits of temperature, some gases have such a powerful affinity for others that they are never found alone. In other words, such a gas, if freed, has an irresistible tendency to combine with other gases and form some other substance. On the other hand, certain gases will not combine at all with others, except under artificial conditions. Thus, whilst

oxygen rapidly combines with iron and forms iron oxide, it does not combine with nitrogen, with the consequence, fortunately for us, that we have an atmosphere consisting of a mixture, not a combination, of oxygen and nitrogen.

It is believed that by such means our Sun, the World and the other planets were evolved in space, combinations of many different gases forming liquids and solid matter. It is known as the Nebular Theory, and was first suggested by the great philosopher, Kant, in the year 1755, long before any nebula had been discovered. Kant arrived at his conclusion simply by reasoning. Astronomers have arrived at a similar conclusion as the result of observation, calculation and unmistakable evidence. The deductions of other scientists have assisted, and in this wonderful theory there are so few flaws, and there is so little wanting to confirm it, that it is now almost universally accepted.

In their silent night watches astronomers have discovered thousands of these luminous spirals in the sky, and probably a sufficiently powerful telescope would reveal millions of them. They are called nebulæ, and each spiral nebula is a system consisting of a sun and planets in course of formation. From our point of view, some are right-handed, some left-handed: others appear end-on towards the Earth like streaks of light.

It should be mentioned here that some nebulæ are of such vast proportions that they are believed to

constitute universes, and to consist of countless millions of solar systems. It is, indeed, believed that our own Universe is such a " nebula," of which the spiral sweep is known as the " Milky Way," and that, in consequence of our solar system being situate well within the sweep, the " Milky Way " appears to us like an encircling band of stars.

CHAPTER II

NEBULÆ—COOLING OF THE WORLD—LAND AND WATER

LET us still imagine that we are in space, before the World began, that we are insensible alike to extremes of heat and of cold, and that we are near enough to one of those great spirals to witness what takes place as the fire mist condenses into planetary orbs that spin and whirl round a mighty central globe. One in particular ought to interest us, for, in ages to come, the flame-swept surface of that white-hot sphere, glimpsed through a dense pall of scorching, poisonous fumes, will cool and harden; land and sea will appear; sparkling water will form rivers, lakes and rippling brooks; trees, grasses, delicate fruits and sweet-scented flowers will grow there; cattle will peacefully graze; and human beings will breathe cool, pure air, and construct their dwellings on firm ground beneath blue skies, in the light and warmth of the Sun.

Meantime, chemical changes on a colossal scale are taking place, for there, in a gaseous or atomic condition, are all the elements of which the World will be constructed. Now all those elements are combining and forming particles of matter in an upper region,

where heat is dissipated in the coldness of space. Falling in vast showers into the flames below, they are vapourized again and again. But still they continue to form, constituting a spherical screen round the flaming mass. As more and more heat is dissipated into space, the showers of elements (to which carbon probably contributes an important share) fall to lower levels before they are re-vapourized. As they do so, they converge into a denser mass, reaching at last a level at which they coalesce into molten patches that appear, vanish and reappear, until a plastic spherical shell has formed round the gaseous globe. The process may be likened to the condensation of steam into water, and the freezing of the water at its surface. As the thickness and weight of the shell increase, it exerts an ever-growing pressure on the contained gases, which burst through innumerable vents. In turn, the gases that escape combine, and add their quota of solid matter to the outer surface of the crust which, as it thickens, becomes firmer, and changes from a white to a red, and finally to a black heat.

Now, all is darkness, save for streams of fire where the pent-up gases blast their way through.

Far above that raging furnace in its frail shell, two other gases, oxygen and hydrogen, have been combining, and forming water vapour which, in cooler regions, condenses and falls as rain. Long before it reaches the surface of the World below, it is re-vapourized and rises again, to repeat the same

performance countless millions of times, until, at last, the raindrops reach the Earth. There, also, they are converted into steam and vapour by the hot rocks.

It must be borne in mind that events are being related very rapidly, and that every paragraph in this chapter may cover a period of millions of years.

But as yet there are no years—no days or nights—as we think of them. Light rays from the Sun cannot penetrate the dense envelope of gases surrounding the Earth, on which, at last, water has collected in scalding pools. Often it is driven up by explosive forces from below, but persistently returns, to find other resting-places.

Now, to the accompaniment of incessant lightning and—were there ears to hear—roars of thunder, commences an age of deluging rain. Hissing as it falls into volcanic vents, rising therefrom in blasts of steam, pouring down volcanic slopes in hot torrents, it is washing the deposits of dust, acids and salts from the fire-scarred rocks.

Rain, rain, rain—beating down upon the Earth's hot crust, cracking, disintegrating, dissolving it, and sweeping down the products to form sedimentary layers in the first rocky sea beds.

Rain, rain, rain—cleansing the air and the Earth, itself fouled and cleansed in the process, in its never-ending service preparing the World for life which, without it, could never originate.

Let us leave that desolate, rain-drenched World of hot, bare rock, in the flame-lit gloom of days

indistinguishable from nights, offering no shelter or sustenance of any kind. Let us return to the World of to-day and, looking back, trace out the course of subsequent events.

We may think of a period following, when the surface of the World was covered with water, through which great fountains of fire burst; of whirlpools of boiling liquid, of rolling masses of vapour clouds enveloping the scene, and of volcanic cones rising above the water and belching forth ash and lava. But we cannot as yet imagine any kind of life.

Meantime, other stupendous forces of Nature have been at work—forces which operate to-day—and of which there is overwhelming proof.

In Chapter I, it was explained how particles of matter all try to reach the centre of any mass they constitute, and how, consequently, they tend to assume a globular form. Similarly, particles constituting the Earth's crust, all endeavour to reach the centre: that is why water always runs down to the lowest possible level. Particles forming solids cannot move independently, but the tendency to do so is there: that is why an object dropped from a height falls to the ground.

If we hold an orange in both hands, and squeeze it evenly all over, we put a *side* pressure on the peel which gives way and begins to bulge in ridges between our fingers. If we press hard enough the peel will burst, the edges will rise, and some of the juice and inside part of the orange will pass out through the

opening. For our purpose, we may compare the peel of the orange with the crust of the Earth, although it is far from a perfect analogy, because, in the case of the Earth, the weight of the shell itself, pressing inwards, takes the place of the pressure of our hands on the orange. So great was the side pressure on the Earth's crust that something had to give way, and that naturally occurred in the weakest parts.

What happened then was that the crust bent upwards in some places and downwards in others, and in that way portions of the sea beds were raised above the water, and, for the first time, land was divided from the sea.

It must not be supposed, however, that land first formed as it now exists, but rather that, as fast as it was upheaved, it was disintegrated and worn away. It is, indeed, reasonable to believe that those early upheavals were on a minor scale, and resulted in comparatively small islands of spongy rock which were speedily obliterated by further upheavals. But as ages passed and the Earth's crust thickened, the curving and crumpling were on a grander scale, and took place more slowly, so that, instead of small islands forming rapidly, continents were elevated in the course of millions of years.

CHAPTER III

THE FIRST LIFE ON EARTH

IF matter be divided into small enough particles, we reach a point where living, or organic matter, becomes indistinguishable from mineral, or inorganic matter; it follows, therefore, that the conditions to which it is subjected must determine whether such minute particles shall take the form of inorganic matter, or whether it shall develop as animal or as vegetable life. This is known as Abiogenesis.

The religious sense of some people is shocked at such an idea, but it is in no way irreligious. It raises no question of the soul. We are told in the Bible that God fashioned man from dust. Adam was told: "Out of the ground wast thou taken; dust thou art, and to dust thou shalt return."

By far the greater part of all living matter consists of water, which, in turn, consists of oxygen and hydrogen. The bulk of the remainder could be resolved into other gases, and the small residue could be vapourized. Given the requisite apparatus, out of those constituent gases, a chemist could produce quite different substances, although it is true that he could not produce living organisms: We have, however, to

consider the fact, now well established, that the atoms of which all matter consists, contain active elements, and it therefore becomes a question whether there *is* such a thing as an inanimate object, in the old, strict sense of the word.

From a piece of flint, an analyst could extract oxygen, combine some of it with hydrogen and form water which, if he drank it, would enter his blood and become part of his body. He could mix the rest of the oxygen with nitrogen and produce air. If he inhaled the air, the oxygen would pass through his lungs into his blood, travel all over his body, combine with carbon, and form a poisonous gas which a plant could inhale, and from which it would separate the oxygen again and exhale it. If the oxygen were then brought into contact with iron, it would combine with the iron and form iron oxide (rust). This is only one of numerous instances that might be quoted of chemical action that takes place on a stupendous scale throughout the World, and throughout the Universe.

How and when life first appeared, and in what form, is not known. The oldest fossilized remains of plants and creatures lead to the belief that it was hundreds, if not thousands of millions of years ago. But, as will be seen later on, Nature closed the record afforded by fossils by crushing together and crystallizing all rocks beyond a certain age, and obliterating every sign of life that may have previously existed. Although the record of the rocks extends through vast periods of time, these periods are so short,

compared with the age of the World, and the record is so broken, that it is comparable to odd chapters, of which many leaves are missing, of a story comprising many volumes. Nevertheless, from what is known of lowly forms of life, some idea may be gained as to the manner in which it originated.

There is every ground for thinking that, in those far off days, the whole surface of the World was in an extremely damp condition and enshrouded in humid clouds. It is reasonable, therefore, to suppose that life first appeared in water, or in very damp places, possibly in the form of slime, and that, once started, such slime would rapidly accumulate and spread. In time, when movements of the Earth's crust raised the sea beds to higher levels, plant life would need to develop the faculty of living at least partly out of water, and, in so doing, would develop roots enabling it to draw moisture from the soil. The idea of plants "learning" may seem curious, but we know that they as well as animals do learn to accommodate themselves to changing conditions, and even to fight for their existence.

It is equally reasonable to suppose that the first animal life also appeared in or near water, and that it was of a very low and miniature type, such as may be seen through a microscope in a drop taken from a stagnant pool or ditch.

In the intensely hot and humid condition of the World in those days, land plants, like lichens and mosses, no doubt spread rapidly, and soon covered

large areas. And, as they died and decayed, their remains mixed with grains of sand, and other ingredients, forming soil in which plants of a higher order, such a ferns, developed.

At this point, we turn for guidance to the geologist whose study of the various rocks of which the Earth's crust is composed, and whose examination of the fossilized remains of creatures and plants that once lived, enable him to delineate the different types in their order of existence.

Unfortunately, in authentic works on geology, the subject-matter is usually treated of in such a learned, but at the same time, disconnected manner, that it is no easy matter to obtain a clear idea of all that is involved. Indeed, it must be confessed that, even shorn of its technicalities, Latin names, and everything of a confusing nature, the subject is not one that readily lends itself to treatment as a narrative.

The materials constituting the Earth's crust may be primarily divided into what are termed stratified and unstratified rocks. Geologists include not only hard, solid substances like granite, but every kind of mineral matter in its natural condition, such as sand, chalk and clay, in their classification.

Stratified rocks are those formed by the disintegration of igneous rocks, and containing the remains of animal and vegetable matter. In every part of the World it is found that stratified rocks are in much the same order. This indicates that first one kind of ingredient of the original rocks was loosened and

washed away, and then others. Each kind was washed down by water, and deposited as a layer. The different ingredients in this way formed many layers, one above another, until the great weight above compressed them to such an extent as to change the lower layers into different kinds of solid rock again, the process being assisted by chemical action. Each layer is called a stratum; two or more layers are called strata, and from this we get " stratified " rocks, which simply means different kinds of rock in layers, in which lie buried the remains of creatures and plants that once lived.

Unstratified rocks comprise the deep-lying portions of original igneous rock formed by the cooling of the Earth's crust, and the lava and other materials ejected by volcanoes.

Stratified rocks are not always in even layers of the same thickness and of the same material: the layers vary enormously in thickness, and even in one particular district may be much thicker in one part than in another. Again, the original igneous rocks may have differed in composition: in some strata, certain ingredients are absent, which are numerous in others. Moreover, a great deal depends upon the manner in which the materials worn away were deposited. When lodged in narrow, deep seas, the strata would naturally be in much thicker layers than in places where they were spread over a wide area, where the layers would not only be much thinner, but might taper off to nothing at the outer edge.

And in still another way were strata formed. Sand blown by the wind is a powerful scouring agent. In some parts of the world to-day there are rocks, the surfaces of which have been heavily scored and worn by sand blown against them by the wind. More and more sand thus accumulated and great quantities were deposited which eventually sank to lower levels, where they were consolidated. Such deposits are termed aerial rocks ; those laid down by water, sedimentary, or aqueous rocks.

One need not be a geologist to take an interest in a piece of stone taken from an open water trough in a coal mine at South Shields, that may be seen in the British Museum. During each night the water deposited a layer of whitish mud, but in the daytime, when the miners were at work, coal dust mingled with the mud, so that, alternating with the white layers are black bands representing the working hours of the day, six black bands at regular intervals denoting six working days a week. Then occur broader white layers deposited during week-ends. Holidays are indicated where fewer than six dark bands occur. Thus, unknown to the miners, their periods of work and rest were silently recorded. This stone is of great instructive interest, for on a small scale it illustrates the manner in which sedimentary rocks of the Earth's crust were deposited by water in past ages.

CHAPTER IV

GEOLOGICAL PERIODS—THE DEVELOPMENT OF LIFE

IN tracing the story of life, there is no degree of certainty until we come to examine the fossilized remains of creatures which are found in the oldest known stratified rocks, namely, the Cambrian. In this are found trilobites—one of the first signs of animal life. The trilobite was a curious sea creature, of which some grew to a length of 2 feet. The earlier ones possessed no eyes, showing that the World was then still dark. Their bodies were ringed, their heads were protected by shields, sometimes branching out into spines, and they were provided with delicate, jointed appendages for swimming. There also are found the remains of small shell fish, such as the lingulella, and sponges, and the impressions of minute water plants called algæ. These things lived in the sea, and were buried in deposits of sand, mud, and the remains of microscopic sea life.

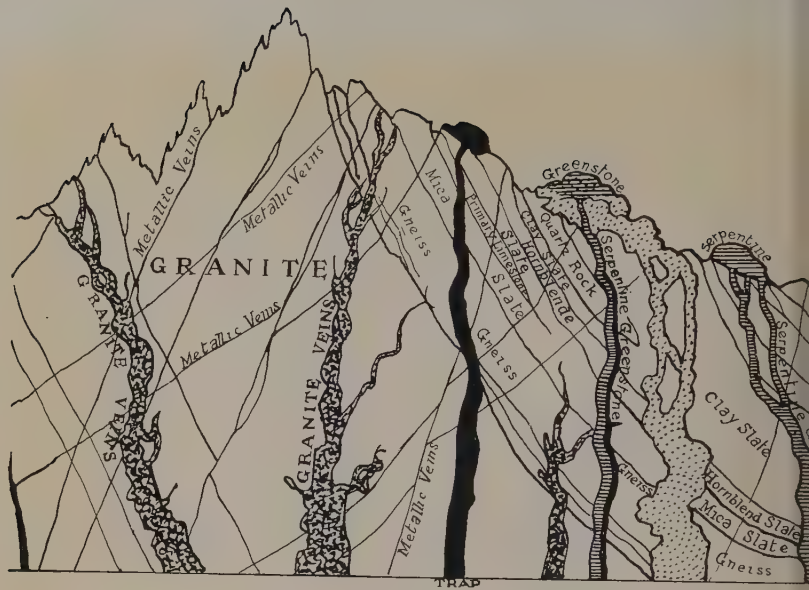
It is perhaps well, at this point, to anticipate one or two questions that are sure to arise in the reader's mind.

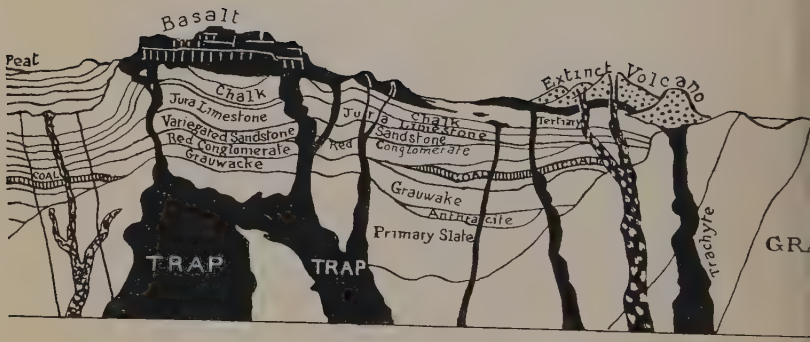
How old is the world ? and how long ago did these

things occur ? The reply is that no one can tell. It is true that attempts have been made to estimate the age of the World, but all such attempts are little better than guesswork. Even if evidence were forthcoming to justify an estimate of say, 800,000,000 years, it would be quite meaningless, since there is every reason to suppose that millions of years ago, the World revolved round the Sun at a very different speed, and probably rotated on its axis far more rapidly than it does now, so that many days then would only be equal to one of our present days. To put it another way : if events then could have been timed by a clock set to keep present-day time, many days might have passed while the hands of the clock indicated 12 hours.

Owing to the difficulty of assigning time values, geologists divided up past ages into " periods," to which different names were allotted, corresponding, more or less, to the development of life. Beginning with the Cambrian, these geological periods are known as the Ordovician, Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Older and Newer Tertiary, and the Pleistocene period during which it is believed that man first made his appearance.

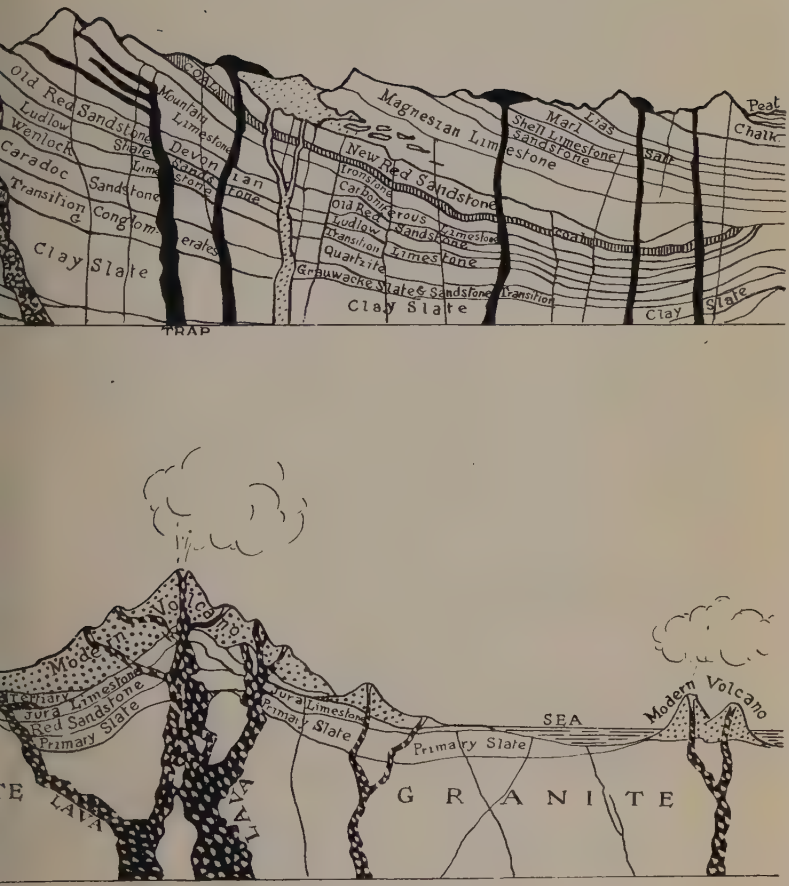
Diagram No. 1 is worthy of study, as it indicates the different periods, and, to some extent, the manner in which stratified rocks were formed. It must be borne in mind, however, that all the strata indicated do not occur everywhere. In places, some may be absent ; in others, certain kinds may be present and





Sections Illustrating how Strata were La

Reading from the bottom right-hand corner to the top left-hand corner, it is seen how volcanic islands are formed by lava bursting through the ocean bed and building up cones above water-level. Further to the left is an active volcanic region upheaved from ancient sea beds, with ejected lava, etc., overlying limestone. Further on are sedimentary deposits of great depth worn away



OWN AND UPHEAVED INTO MOUNTAIN RANGES

rom old volcanoes of which but the skeletons remain, with chalk above proving that they were nce beneath the ocean. Following these strata to the left (in the upper part of diagram) it is een how upheaval of the Earth's crust elevated mountain chains, and how the edges of the strata vere upturned and exposed, until gneiss and granite were thrown out.

others lacking, whilst in many cases, disturbances and upheavals have upset and disarranged them.

Reference has already been made to a few of the earliest forms of life: long ages passed whilst those simple types, such as small shell-fish, trilobites, and a curious creature that looks half-insect and half-fish, called hymenocaris, multiplied in the seas.

In the strata next above the Cambrian are found the remains of new kinds of shell-fish, corals, sponges and seaweed, and of trilobites which had developed eyes—showing that the Sun's rays were beginning to reach the World, though but feebly as yet.

As time passed, the curving of the Earth's crust caused ocean beds to rise and become shallower; with the consequence that descendants of many of the creatures that lived in deep water were obliged gradually to accustom themselves to new conditions, as well as to a climate which was slowly growing cooler. Those different conditions caused important changes in the living things inhabiting the seas, many of which altered greatly in size and form.

Fish made their appearance, then water reptiles, whose descendants developed lungs, enabling them to breathe out of water; and scales to protect their soft bodies from injury on hard ground. Thus, land creatures were evolved, including flying reptiles with webbed wings.

While animal life was thus progressing, Nature was not idle in other respects. We may suppose that slime in water developed in time into seaweed, and

into mosses and lichens that spread away from the water's edge. And, as we find to-day, fern-like plants made their appearance in the mosses, lived their life, and died. The decayed remains of animal and vegetable matter mingled with mud and sand, forming soil that absorbed moisture, and in that way afforded more and more nourishment for vegetation. Where vegetation grew thickly enough, we may suppose that it constituted barriers that obstructed mineral matter washed down from heights. This mineral matter in turn formed dams, causing water to accumulate in pools and lakes. Thus, by various means, soil and vegetation gradually spread.

True, feathered birds, with toothed beaks, and mammals of great size and of many species, at last peopled the World, fossilized remains of all these being found in many parts.

Life also abounded in freshwater lakes, into which water flowed, bringing down sediment just as it did into the sea. Freshwater strata were thus formed, although not on such a grand scale as in the ocean.

Again, on land where vegetation flourished, the remains of animals and of vegetable matter were buried. Heavy floods sometimes carried away such deposits to lower levels, where in due course they were covered over. In some cases the land itself gradually sank, and one growth of vegetation succeeded another in the same locality, each being buried and eventually converted into coal by pressure, heat and chemical action.

Thus, the process of life development went on, age after age, the numbers of living things and the number of species ever increasing, the different strata deposited serving as cemeteries for their remains. The older types did not always die out. Some persisted through many ages and existed side by side with much more highly developed species.

Between the great Geological periods, there were intervals of time, of which, at present, there are no records. Whether these intervals were long or short, and whether from their closed pages we are to infer gradual change or catastrophic events, is matter for conjecture. But of one thing there can be little doubt, and that is that they were due to changes or reversals in the movements of the crust of the Earth, resulting in comparatively rapid elevation of large tracts of land to higher and colder altitudes, and the extermination of certain species in those parts.

It is not, therefore, to be supposed that the process of evolution took place everywhere at the same time; for there is evidence that influences operating in one part of the World did not make themselves felt in other parts until millions of years afterwards.

CHAPTER V

ROCKS—AND THE STORY OF LIFE UNFOLDED BY THEM

IN order to follow this chapter, it is necessary again to refer to the table and diagram No. 1. Below the Cambrian are other rocks, in some places 4 miles thick, of a more or less crystalline character. Lines marking divisions between what appear to have once been different layers, lead to the belief that they have undergone stratification, although if they contain the remains of life that existed before the Cambrian period, all trace of such life, except that of doubtful worm burrows, is obliterated. They are known as "Transition" or "Metamorphic" rocks, and comprise gneiss, schists and quartz.

Underlying them is granite—original igneous crystallized rock. Granite is a greyish, speckled rock of extreme hardness, consisting of four principal kinds and varying according to the quantity of four of the chief materials entering into its composition : namely, felspar, quartz, mica and hornblende. These vary in colour, felspar being red, pink, green or greyish white ; mica sometimes black, sometimes white ; quartz generally colourless, but occasionally a milky white,

whilst hornblende is dark green or black. Minute globules of liquids and bubbles of gas were imprisoned within the crystals during formation, millions of these microscopic cavities often occurring in a cubic inch of granite.

It is an interesting fact that crystals of granite closely resemble, in certain respects, those of lava thrown up by volcanoes.

Rocks overlying granite are curiously affected, and in some cases are altered so much for a considerable depth that it is difficult to distinguish them from granite itself. Again, in many places, veins and walls or dykes of granite protrude into them, such veins or dykes being probably the result of downward curves of the Earth's crust, which, putting tension on the lower surfaces of the bends, split them, allowing fluid matter to penetrate the cracks. Subsequent compression, due to reversal of curvature, changed this fluid matter to granite.

Thus we trace the wonderful cycle of operations, by which the original lava of the Earth's crust was transformed, worked and washed about into layers, mixed with animal and vegetable matter, lowered to great depths and reconverted into crystalline rocks.

What occurs below granite is not known ; possibly there may be a layer of what, under ordinary conditions, would be termed molten material, but which, subjected to such pressures at this great depth would not, could it be seen, resemble ordinary molten matter in the least.

In the Ordovician strata, overlying the Cambrian, we come across the first radiolarians—sponges, star-fish, curious cylindrical shell-fish; coral; and trilobites in every stage from young to fully-developed specimens, as well as strange creatures (graptolites) resembling fern leaves.

In the Silurian strata, impressions of scales and fins indicate the first appearance of fish. Corals and burrowing worms are in evidence, but vegetable remains are confined to seaweed. Shell-fish included many new varieties.

Later, in the Devonian system, a freshwater creature, called the pterygotus, appeared; corals were still abundant, and very interesting specimens of freshwater fish were also found, such as the cephalaspis, that looks like a descendant of the hymenocaris. Other fish were the polypterus and the osteolepis, bearing a resemblance to a species now indigenous to African rivers. Some of the fish of this period attained a length of between 20 and 30 feet, their scales being like bony armour. It is in the Devonian strata that insects are first found. One was a kind of large May-fly (*platephemera*) measuring 5 inches from tip to tip of the wings; another, a flying insect resembling a grasshopper. Here, also, can be seen specimens of plants and trees, chiefly of a fern-like character.

Now, as we follow the rocks upward, our discoveries become more and more interesting.

In the Carboniferous strata new kinds of shell-fish appear, of spiral formation—the forerunners of the

ammonite; specimens of the nautilus also being revealed. Here, too (of what vital importance to us!) coal occurs, alternating with layers of shale, in such quantities and so distributed as to prove that tropical vegetation must have flourished in great profusion. Tree-ferns grew to a height of 60 feet, and measured as much as 15½ feet round the base, while roots corresponding in size to the trees, and many fossilized fruits have been discovered. Imprints, too, of the leaves themselves often appear on the rocks of the coal measures. In one coal mine, 30 trees were once found in an upright position, just as they grew, within a space measuring 7 yards square.

Many specimens of the Carboniferous strata bear the impression of raindrops on the material when it was softer and above ground; others, footprints resembling human handprints, proving the presence of animals that could leave the sea and walk on land. Insects resembling scorpions, spiders, beetles, cockroaches, crickets, ants, grubs, landsnails and worms were numerous.

Amphibians now appeared, such as the archegosaurus minor, a curious creature that may have descended from the cephalaspis of the Devonian period. But it was for its luxuriant vegetation that the Carboniferous period is generally considered notable. The Sun was by this time making itself felt, and shedding light upon the Earth; not sunlight as we know it, but sufficient to influence the development of animal and vegetable life. It was probably no brighter than

is experienced just after sunset on a summer evening. The World then still depended upon its own internal heat for surface warmth.

The Permian period produced fish resembling species known to us to-day. Amphibians had multiplied in great numbers, exhibiting features proving that they were in a transition stage between water and land reptiles. True reptiles, like lizards and crocodiles, also developed in this age, some of which, in turn, appear to be the connecting links between reptiles and mammals. New kinds of plants and trees sprang up, including tree-ferns with trunks covered with dense masses of air roots, making them appear several times their real size, like certain species that grow in New Zealand to-day.

During the Triassic period, the tiny coral—individually insignificant, collectively the greatest of marine engineers—was at work constructing reefs which, in a compressed form, now constitute whole mountains—notably, in the Tyrol. Shell-fish, including ammonites, were plentiful, and fish of the shark species appeared.

Amphibians abounded, and marine reptiles, such as the lariosaurus, from which the icthyosaurus and plesiosaurus of the following ages descended; also crocodiles, dinosaurs and land reptiles. Many of these appear to have been in a transitory stage between reptiles and mammals, such as the placodus gigas, and the tritylodon. Another peculiar creature was the hyperodapedon, with skull and beak resembling

GIANT FERNS OF WHICH OUR COALS ARE MADE

PLESIOSAURS

Different species ranged from ten to forty feet in length.

those of birds. In New Zealand to-day there are lizards similar to the hyperodapedon—evidently descendants of that species that were able to multiply and so continue the race through many ages, although in other parts of the World they became extinct.

The lapses of time between the different geological periods are believed to have been of greater length than the periods themselves, although it has also been suggested that they indicate sudden and catastrophic upheavals. However that may be, during those " breaks," as they are called, there must have been great alterations in the condition of the World to affect the development of life as it was affected between the different periods.

By such means Nature rendered indecipherable many chapters of the Record of the Rocks, leaving no clue to the missing links in the evolution of life. We can only suppose that during each Geological period climatic conditions enabled life to progress favourably, and that afterwards, owing to local elevation and subsidence of the Earth's crust, these conditions altered, new ones arising unfavourable to all but the strongest and most persistent forms, able to accommodate themselves to the lower temperature of higher altitudes, and to develop accordingly. Such changes, however, did not occur all over the World simultaneously, and ages may have elapsed between similar events in different quarters of the globe.

In the Jurassic period, marine life included new kinds of fish, sea-urchins, brittle starfish, ammonites

and other shell-fish in great numbers. It was during this epoch that those great creatures popularly known as "antediluvian monsters" made their appearance, some of them growing to a height of between 20 and 30 feet, among which are included the plesiosaurus and icthyosaurus, both inhabitants of the sea. Of land reptiles, the most impressive specimens were the scelidosaurus, megalosaurus and iguanodon: creatures that walked on their hind feet, leaving impressions like those of a bird, the megalosaurus, in a natural standing attitude, being 25 feet high. Another gigantic reptile, that walked on all fours, was the brontosaurus, 70 feet in length. Flying reptiles, of various sizes, with long, toothed jaws and webbed wings, also came into being, including the pterodactyl, whose wings in some cases measured 25 feet from tip to tip. It was in the Jurassic period that birds (*archæopteryx*) with feathers first appeared. Although they were true birds—not flying reptiles like the pterodactyl—their beaks were toothed, other points also indicating their descent from reptiles. Mammals were represented by small animals about the size of rabbits and cats.

Trunks of fossilized, coniferous trees have been unearthed, with stumps and roots in the positions in which they grew. These trees attained a height of as much as 23 feet from the ground to the branches, and a diameter up to $3\frac{1}{2}$ feet. In some instances, curiously shaped bodies (*mantellia nidiformis*) like petrified birds' nests are found—trees compressed

and squashed downwards by the weight of the strata above them—bearing a similarity to an East Indian tree of the same species.

In the Cretaceous period some of the gigantic Jurassic reptiles were missing, although the iguanodon, icthyosaurus, plesiosaurus and pterodactyl still survived. A monster snake-like water creature (mosasaurus) now revealed itself. Fish of the shark species multiplied, and shell-fish of the ammonite type grew to great sizes. Sponges developed enormously, and are found in chalk hills in a silicified condition, due to silica in solution percolating the chalk and impregnating and surrounding them with flint. Mammals do not appear to have developed much beyond the stage they had reached during the Jurassic period, but there is evidence of such birds as the hesperornis and ichthyornis.

In this strata the remains of animal and vegetable matter have become fossilized in a strange manner. Water containing silica in solution percolated the chalk, dissolving the original matter and depositing the silica which crystallized into solid forms of exactly the same patterns as the original objects. In other cases, it accumulated around shells which are now sometimes found inside masses of flint.

CHAPTER VI

ROCKS AND THEIR STORY—*continued*

WE are now approaching the end of the story of life disclosed by the stratified rocks, but it must be remembered that, although they have been dealt with so briefly, vast periods of time were required for their formation.

On the surface of some of the clay rocks of the Cretaceous system are cracks, showing that there were spells of dryness, and apparently indicating that the World was by that time deriving appreciable heat from the Sun.

From the Cretaceous, we pass upward through the Older Tertiary strata. In this, corals, oysters and shell-fish of many kinds were abundant, and crab and lobster-like creatures had come into existence. Fish, especially sharks, swarmed in the seas, and included sword-fish and saw-fish 10 feet long, pike and gigantic rays. Armoured fish had now almost disappeared. Reptiles were represented by the lizard, tortoise, turtle, crocodile and bat. Sea-serpents and land snakes made their appearance, the former reaching a length of 20 feet. A few new birds had developed, such as the odontopteryx, with serrated jaw bones instead of teeth which characterized the earlier kinds,

and birds like the albatross, vulture and kingfisher.

Some of the mammals combined features which are now found in several different and distinct species indicating a line of descent. There were many varieties of all sizes. The xiphodon was like a deer, and the hyopotamus resembled the hog. Others resembled the hyena, bear, opossum and lemur, although true monkeys had not as yet made their appearance. The palæotherium was a tapir-like animal about 5 feet high, the size of a small horse. Whales grew to a length of 70 feet. Among larger animals there were huge quadrupeds, of which the tinoceras and dinoceras are examples. Carnivorous animals had increased in great numbers.

The insect world comprised monster ants, dragonflies with speckled wings, grasshoppers, butterflies, moths and land snails.

Trees and plants included many present-day varieties, such as the beech, oak, elm, plane, lime, birch, poplar, fig, hazel, palm, willow and fern. There were also water lilies and vines, while many kinds of fruits have been discovered. In those days the northern hemisphere was obviously warmer than today, for poplar, beech, plane and lime trees grew within 12 degrees of the north pole, and at a later period the magnolia not only grew within what is now the arctic circle, but bore fruit there, whereas nowadays only a few very hardy species of plants survive in those regions.

It must not be thought that the forms of life peculiar to any period existed all over the World at the same time. Some flourished in some places, and others in other places, much as different trees, plants and animals are found in different parts of the World to-day.

During the Older Tertiary period many mountains, such as the Alps, Pyrenees, Carpathians and Himalaya had not yet formed.

In the Newer Tertiary strata are found numerous forms of marine life that exist to-day, although many others are extinct. New types of plants, such as the magnolia, smilax and various water lilies and flowering plants flourished. Insects were abundant and in great variety; in some cases their very colours have been preserved.

This period is principally interesting on account of further development among mammals. The hippotherium was the ancester of the horse. Other types resembled the deer, antelope, goat, ox, sheep, pig, camel, giraffe, dog, wolf, lion and bear, and smaller creatures like the otter and beaver, as well as monsters like the rhinoceros, hippopotamus and elephant. The mastodon, dinotherium, helladotherium and camelopardalis are instances of monsters now extinct. But at least as interesting as any are the remains of apes which have been found—the first true members of the monkey tribe in the history of the World.

We now arrive at the last of the great geological periods, namely, the Pleistocene.

By this time, the Great Work of Creation had rendered the World a habitable place for Man. Light divided the day from the night, and the Sun, Moon and Stars were visible in the firmament. The land had been divided from the waters—nay, more—Nature had ground and sifted it, lifted and turned it as with a vast, invisible plough, and harrowed, watered and prepared it for life. Creeping things and vegetation performed their share of the task. Fish had appeared, then reptiles, birds, and the beasts of the field. The Divine Commands had been fulfilled—with one exception.

And then God created Man, and endowed him with reason and with the knowledge of good and evil to lift him above the level of the brutes—gifts which he has steadfastly abused ever since. Man was created and exhorted to multiply, and his seed was destined to exercise dominion over the fish of the sea and the fowl of the air and the beasts of the field.

Although many may regard the appearance of Man as an event which throws the development of other life into the shade, we may deal, if only briefly, with further wonders of the Pleistocene period.

Among the animals were kangaroos, some of gigantic size, and monsters such as the scelidotherium and megatherium (giant sloths), the diprotodon, mylodon, mammoth and others. Ostriches grew to a height of 11 feet. The lion, bear, wolf, reindeer, horse, and indeed, most of the present species of animals great and small, were represented, including monkeys.

In the Pleistocene period there were great underground caves and natural tunnels in many parts of the World, caused by subterranean flows of water, which temporarily ceased. Some of these caves were inhabited by the animals and men of those days. Afterwards, water found its way into them again, gradually filling them with debris.

Such caves are sometimes excavated and skeletons disclosed. Bones of carnivorous monsters are discovered mingled with human remains, as though men had met with an untimely end. In other cases, human bones, with flint knives and hatchets, are found with bones of herbivorous animals, proving that those prehistoric men were by no means vegetarians. In one cave in Yorkshire, the remains of about 300 hyænas were unearthed, and in the same cave were bones of the ox, horse and other animals gnawed by them.

Mounds have been discovered measuring as much as 1000 feet across and 10 feet high, consisting entirely of the shells of oysters, and other edible shell-fish, indicating our forefathers' taste for the "succulent bivalve" and toothsome cockle. In these heaps were knives and hatchets of bone, wood, horn and stone, with pieces of rude pottery, while charcoal and ashes prove that our early ancestors knew the use of fire.

In other cases, animal and human remains are found in ancient gravel beds, together with similar instruments. The earlier implements were merely chipped, so as to present a rough edge, and in many

THE EARLIEST KNOWN FOSSIL BIRD (ARCHÆOPTERYX) AND A SMALL DINOSAUR (COMPSOGNATHUS)

This bird was about the size of a large pigeon. Notice its teeth and the claws on its wings.

THE HORNED REPTILE TRICERATOPS

Notice its spine-bordered frill. It was 25 feet long. From the Cretaceous rocks of Wyoming. In the right-hand corner of the foreground is the head of the giant amphibian, Mastodonsaurus, from the Trias of Germany; its head is 4 feet long.

instances the edges are worn, showing that they had been used as scrapers. At a later period they were polished, and fitted with hafts of bone or wood.

Bone needles, with carefully drilled eyes, and pieces of a kind of cloth made from woven flax or straw, are among other things found. In one cave in France, the horn of a reindeer was unearthed, on which was rudely carved the outline of a mammoth, showing that Man must have existed at the same time as that huge animal.

In the Swiss lakes, prehistoric dwellings, and indeed whole villages, have been discovered, evidently built over the water on thousands of wooden piles and afterwards inundated. In these districts, hundreds of rough instruments, principally of stone, have been dredged up from the lakes.

It is owing to the use of flint that this early period of human existence is called the Stone Age.

In the lower deposits of some peat beds, similar stone implements are found. Higher levels, represent a later period when instruments of copper and bronze were employed in lieu of flint, proving that in time our predecessors learnt how to procure copper and tin. That period is known as the Bronze Age. At still higher levels, iron implements come to light; Man had at last acquired the art of smelting iron: and with that discovery began the Iron Age. It must not be supposed that all these so-called Ages occurred simultaneously all over the globe. In some parts Man had advanced to the Iron Age, while in others

he had not progressed beyond the Stone Age. Even to-day certain savage races use stone implements, and may be said to be still in their Stone Age.

Burnt grains of wheat and barley, and pieces of bread, have been unearthed, indicating that during the latter part of the Stone Age the cultivation of land had begun.

The slow progress of Man towards civilization is illustrated by the manner in which the implements of the Stone, Bronze and Iron Ages are associated with the bones of different animals. Thus, with flint instruments are found the bones of deer, the wild boar and the wild ox, demonstrating that Man first hunted for his food. With bronze instruments are found the bones of the domestic ox, goat and pig, as though Man had begun to keep animals in captivity. Pottery of the Bronze Age was better in form and quality than the rude vessels of the Stone Age.

During the former, Man must have begun to trade, because, although tin and copper, the essential ingredients of bronze, are not found everywhere, but often in places far apart, bronze implements were quite common all over those territories now known as Europe and Asia. In some cases—possibly where tin could not be obtained—instruments were made entirely of copper.

In the early part of the Iron Age rough attempts at coinage are found for the first time.

Notwithstanding all these evidences of Man having multiplied and occupied great areas, comparatively

few human remains of the Stone and Bronze Ages have been discovered. Some archæologists attribute this to a custom that may have prevailed of burning the dead, but a simpler explanation that suggests itself is that burial rites were not practised, and that Nature's processes having slowed down, such remains were not preserved, as in the case of earlier forms of life, but decayed and rotted away.

During the Pleistocene period, although the shape and character of the land may have been very different from what it is now, probably the division of land and water in a continental sense was roughly the same as at present. One reason for so thinking is that the living descendants of creatures that inhabited the different continents are of special types, as though there were no land communications between them, as, for example, between Australia and Africa, or between Asia and America. Thus, it is only in Australia that the remains of giant kangaroos of the Pleistocene period are found, and Australia is the home of the kangaroo to-day.

It may appear at first sight incredible that creatures like the icthyosaurus should have descended from fish; that a brontosaurus should have developed from swimming reptiles; and that reptiles should be the ancestors of birds. Yet, when one comes to analyze certain facts, it seems less astonishing. To begin with, these developments took place almost imperceptibly, and during millions of years. In the next place, there is a tremendous variety even to-day

in animals of particular species. Thus, in the monkey world are specimens differing greatly in important characteristics, such as the so-called flying lemur and the man-like ape.

The average person, asked to define "evolution," is at a loss to find a reply at all. Perhaps the commonest is that, according to Darwin, men are descended from monkeys! As a matter of fact, Darwin did not say so: according to his theory, men and monkeys descended from common ancestors —hence the speculation on, and endeavour to trace, the "missing link." Although, for the moment, we are more particularly concerned with the evolution of life, it must not be forgotten that the term applies to Nature's whole scheme: to the evolution, not merely of Man from animal ancestors, but to the vast cycle of operations under which nebulæ are transformed into solar systems, worlds are formed, and life appears and develops, from the lowest to what we are pleased to call the highest type.

The definition, then, of evolution is the development, from a state of chaos, of the World and everything in it as it appears to-day, by the slow, orderly processes of Nature. Lack of space precludes consideration here of such points as "natural" and "artificial" selection, important though they be.

Those, whose complacent pride forbids it not, may reflect that between men and animals there is much in common. They are subject to like emotions, senses and instincts. Notwithstanding the value of speech, and

the advantages—real and imaginary—of education, far more nearly perfect understanding is often established between men and animals than between man and man. Again, medical evidence shows that in the embryo stage a human infant passes through phases strangely suggestive of prehistoric ancestry. We smile at the locomotion, on all fours, of a child of tender years, without reflecting that, but for example and tuition, it would continue thus for the remainder of its life—save for occasions when, following natural instincts, it might possibly stand erect in order to climb trees ; or that, but for such example and tuition, it would utter nothing but gibberish.

Every human being is possessed of organs or parts which, so far as he is concerned, are redundant, but which correspond to features serving a useful purpose in lower animal life. The rudimentary bones of the tail are a useful reminder.

Even to-day there are evidences that evolution is still in progress : species of insects and plants have appeared which did not exist a hundred years ago.

In the course of a few days we witness the transformation of a tadpole to a frog ; and a repulsive-looking grub changes to an exquisite butterfly. Although such changes do not constitute development of species, they are quite as miraculous, but because they are such common occurrences, we are apt to think little of them.

On the other hand, there are not wanting instances of natural degeneration. For example, birds like the

kiwi and the ostrich have lost the power of flight. Arrived in a land of plenty, the kiwi found it unnecessary to use its wings in search of food, or to escape from enemies, and thus, in the course of time, they became superfluous, and deteriorated into almost useless members. The greater the use of an organ, the more Nature develops it in order to serve a purpose which it has hitherto been unable to fulfil, but she will not tolerate a useless member of any living thing.

CHAPTER VII

THE LIFE OF THE EARLIEST MEN

AS an interesting speculation, let us devote this chapter to an imaginary sketch of the kind of life probably led by the early members of the human race.

Picture the World, then, without a trace of civilization. Not a house—not so much as a mud hut—not a road. Nothing but swamps alive with crocodiles and other fearsome creatures ; and plains and primeval forests bearing the tracks of terrible monsters that crashed their way through thickets, feeding on the foliage at the tops of high trees, or pursuing and preying upon other animals.

Now, imagine a band of naked men, hairy and of savage appearance, armed with clubs of wood and stone, prying about among the rocks, seeking a cave wherein to shelter and avoid the unwelcome attentions of beasts of prey. Imagine, as they peered into the gloom, some monster appearing from its dark interior, snatching one of their number, and retreating to devour him in the darkness.

Constant warfare must have been the order of the day between the first race of men and animals which had hitherto held sway on the Earth, and it is difficult

indeed to think of Man then as the lord of creation—one rather pictures him bolting for dear life from natural enemies. But it was there that Man's brain —removed though it probably was by but a step from animal instinct—enabled him to realize that unarmed he was helpless, and that he must therefore arm himself against aggressors. Thereupon he set to work and fashioned rough clubs for offence and defence. And we may suppose that his motto was " safety in numbers," and that, with the instinct of self-preservation, men lived and hunted in bands.

It is not difficult to picture battles that must have taken place, such, for instance, as one between some savage monster, bigger than an elephant, and a dozen—possibly fifty of those primeval men armed with clubs of stone, with rough hafts of bone or wood. Attacked on all sides, their enemy would perhaps crush, rend and destroy many of them, but cunning and numbers would tell, and in the end their clubs would prevail. While the battle raged, packs of snarling hyænas would collect, and when it was over, make short work of the carcase and of the dead men.

Or it might be a battle with a bear for the disputed possession of a cave, or with wolves whose appetite for men had been whetted by the taste of human blood.

And in caves where men held possession, we may think of their womenfolk and children, naked as the men, scarce venturing into the daylight. An evening stroll in those days must have been fraught with tumultuous excitement.

PITHECANTHROPUS ERECTUS, *DUBOIS*

The skull fragment found by Dr. Dubois in Java is of a creature almost exactly on the boundary line between man and the higher anthropoid apes

Restored according to the directions of Professor Rutot of Brussels

Tired of such confinement, it is easy to suppose that they would extend their domains by rough palisades of timber, to keep out intruders. Also, that they would sooner or later discover that certain animals good for food, if taken alive, would breed and render unnecessary many of the risks formerly incurred in providing means of subsistence. And that, by tilling the ground, it could be made to yield grain.

It is an old and true saying that, " The more we do, the more we can do ; " and that in doing one thing, we are unconsciously preparing ourselves for doing another—perhaps something quite different.

In the exercise of those rough works to serve a definite purpose, men had thought and exercised their brains, and having achieved their object, had more leisure to think again. They could scarcely have failed to notice that when wood is rubbed, the friction produces heat ; and that when stones are sharply struck together, they emit sparks. In the absence of kinemas and wireless, we may even suppose that they would indulge in such things merely to amuse themselves, and that one dry day they set fire to some inflammable material, and perhaps started a conflagration, which terrified and yet interested them. And that, when the fire was over, upon exploring the devasted area, they found the roasted remains of animals which, upon trial, proved more palatable than raw meat. It would not need the brain of a modern scientist to realize that a fire might be made and kept within bounds, and that thereafter they

might make fires whereby to cook their meat. A natural consequence would be to notice that, when the fire was made on clay soil, the clay became baked as hard as stone. Sheer lack of other amusement might easily lead them to mould the clay into shapes and bake it. And, either as a result of thought or of accident, a rough jar or bowl would then be made, and found to hold water. If baked once, why not twice ? Mere curiosity would lead them to boil water, and what more natural than to want to see the effect of putting meat and other things into it ? We may feel pretty certain that soon after fire was discovered, our ancestors enjoyed stews as good as any that are made to-day. And if meat could be so much improved by cooking, why not grain ?

By this time, our forebears were doubtless pluming themselves upon their wonderful achievements, and thinking how clever they were ! There is nothing more inspiring than success, and it is natural to suppose that they soon began to tire of chipping flints into rough-cutting instruments. Probably some of them had brains that tended towards engineering matters, and enunciated a theory that if, instead of a blunt edge, their flints could be made with a sharp edge, they would cut more easily. Those pioneers, no doubt, then set to work experimenting, and found that by rubbing long enough, quite sharp edges could be ground. Then, grinding made the flint look much neater, so why not grind them all over ? It is a pleasing fancy to picture whole canteens of those stone knives

ground and polished, and we may imagine Mrs. Prehistoric Jones showing Mrs. Prehistoric Brown her family canteen of one dozen large and one dozen small, polished stone knives, in a horn or ivory case.

At this stage, these early engineers were presumably regarded by their fellow, as supermen, and had to do something more to sustain their reputation—although, in all probability, like our modern supermen, they achieved more grievous blunders than successes. One day, by a lucky chance, they must have come across a soft, reddish-coloured metal (copper). Inquisitiveness would lead them to hack at it, and to the discovery that it could be hammered into rude shapes. Again, they, or engineers of other tribes, after making fires in certain places, discovered layers or streaks of a white sparkling metal (tin) and, upon closer examination, found drops or strings of it on the stones they had used to surround their fires. Observing that this only occurred when certain very heavy black stones (tin ore), quite different from all other stones, were used, in their quest for more of the attractive metal, doubtless they collected quantities of this ore and tried it in their fires. Seeing how readily the tin melted, one may suppose that they tried (but unsuccessfully) to melt copper. Then, either by accident or design, they discovered that when tin and copper were both placed in the same fire, they fused together and formed another metal (bronze). That must have surprised them considerably, and enhanced their reputation enormously as supermen: it is even possible

that this discovery ultimately led to the dream of the alchemists of old, whose ambition was to change lead into gold.

There is good reason for believing that it was in Cornwall that this discovery was first made, and it may be that in that way the export trade of England commenced, for history tells us that the ancient Phœnicians exported tin and bronze from this country to all parts of the World.

The delight of those primitive engineers must have been great at finding themselves in possession of the secret of producing such a useful and easily-worked metal as bronze. Doubtless they regarded themselves as in a highly advanced stage of civilization, and one may picture various refinements of the smith's art, such as improved instruments of torture and personal ornaments. It is a pleasing fancy, indeed, to think of a bronze plate outside a cave, bearing the legend, "BROWN, CONSULTING ENGINEER."

Again, imagine Mrs. Prehistoric Brown's satisfaction when having stung her husband into action on account of the Jones' stone knives, he presented her with a set of bronze or silvery tin armlets and anklets in which, with a few feathers and a little bit of fur, she visited Mrs. Prehistoric Jones. And her delight as she bestowed a feline kiss upon her dear friend and noted the baleful gleam of jealousy in her eye!

When iron ore was discovered, the first step would be to try it in the fire, and after some experimenting,

it would be found that the molten mass could be worked about and forged so that the particles of iron and rock separated. Thus, the advantages of iron knives and other instruments over soft bronze ones became obvious, and bronze was superseded by iron.

We must not suppose that all these discoveries were made rapidly one after another. It may have taken scores of thousands of years to pass from the Stone to the Iron Age.

The brains of those early men probably worked slowly for many generations, and very likely the more intelligent among them, being naturally the more inquisitive, found their way into the stomachs of man-eating monsters. And generations may have passed before their equals were born. In those days fire and curiosity must have been responsible for most inventions.

It is an interesting reflection that, since man made his appearance, the human race has multiplied until it now numbers more than 1,600,000,000 souls, a quarter of whom reside in the British Empire. If all these people joined hands, they would form forty rows round the World at the equator, or a total length of a 1,000,000 miles—4 times the distance from the Earth to the Moon.

CHAPTER VIII

THE EARTH'S CRUST AND INTERIOR

AS time passed, the Earth's crust thickened more and more. What its present thickness is no one can say—it may be 100 miles or more, or even less in places. Enormous as such a thickness appears, it is but a comparatively thin shell surrounding the gaseous interior. The weight of the crust upon these gases sets up tremendous pressure, equal to hundreds of tons to the square inch. It is said that masses of flint, subjected to such compresssion, have been worked and kneaded like dough, pebbles being sometimes found forced into each other, whilst boulders of granite have been pressed into flat slabs, which can be split like slate, and used as roofing-tiles. Gases in the interior of the Earth, exposed to such pressures, are probably as dense as the hardest solids.

The Earth measures 24,700 miles round, and nearly 8,000 in diameter, which means 4,000 miles from the surface to the centre. We may roam about the surface as much as we please, and even fly in the air, and grope beneath the water in submarines. Yet, although we think nothing of walking 7 miles, so far we are

unable to ascend to a greater height than that; while our knowledge of subterranean mysteries only extends to a depth of about 20 miles out of 4,000. Even that much is only what Nature shows us, for Man has never bored to a depth of more than about a mile.

A piece of chalk, taken from a hill hundreds of miles away from the sea, and thousands of feet above sea-level, prepared in a certain manner and examined under a sufficiently powerful microscope, will be found to consist almost entirely of exceedingly minute sea shells of many curious and beautiful forms, and ooze dredged from a depth of miles beneath the ocean, when similarly examined, is found to consist of somewhat similar forms of life.

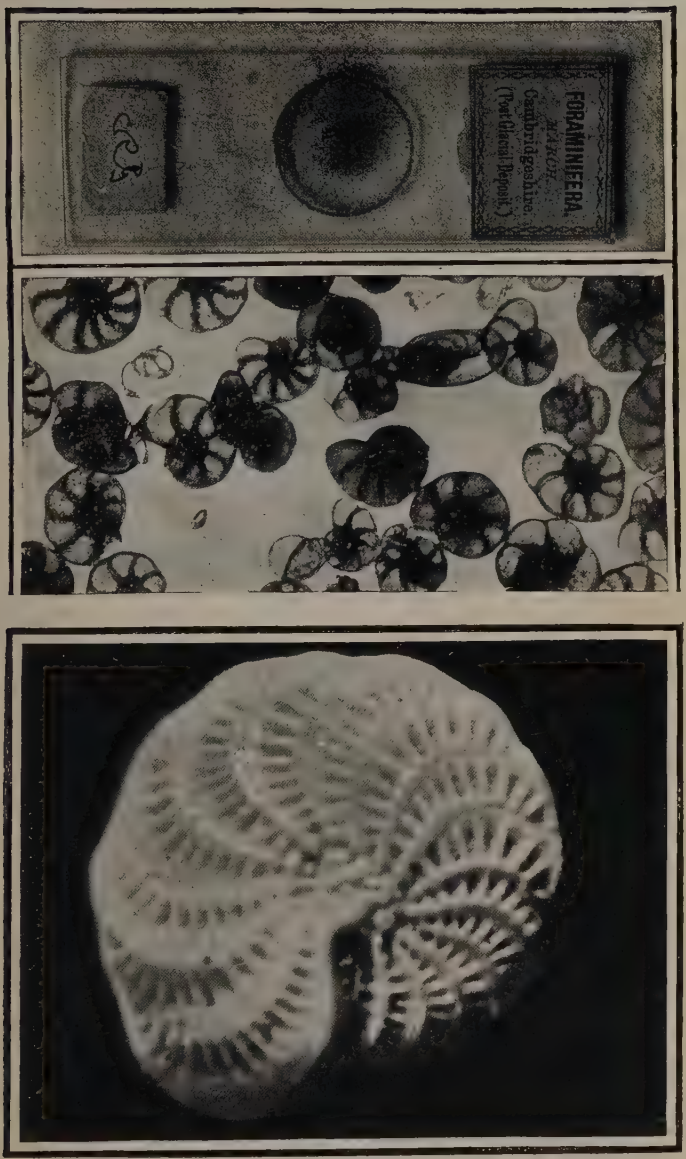
These tiny creatures, known as globigerinæ and radiolarians, do not live in fresh water. Now, chalk forms a great and important portion of the Earth's solid crust. In some parts of the World there are ranges of hills extending, with breaks, for hundreds of miles in length and breadth, consisting almost entirely of chalk thousands of feet thick. These great masses are made up of the remains of microscopic creatures which are only found in the sea, and of the remains of which ocean beds consist. Fossilized sponges are sometimes found in the chalk, round which solid casings of flint have formed, resembling great pears. They are known as pot-stones, and some measure 3 feet long by a foot in diameter.

On the tops of many high hills are beds of gravel containing pebbles, worn and rounded just like those on the seashore, and which could only have been so worn by the rolling action of waves. Those beds of gravel are ancient sea beaches, and in them are the fossilized remains of creatures that once lived in the ocean.

In the Alps, and in other parts of the World, are rocks, thousands of feet above sea-level, consisting entirely of coral, although that animal never builds above water-level. Again, in the Himalaya mountains, fossilized sea shells are found 18,000 feet above the sea.

In some cases, fresh-water shells, and fossils of land animals and plants, are discovered below strata containing remains of marine creatures; also, fossils of land animals and plants far below sea-level. Coal (fossilized trees and vegetable matter) is actually mined in some places beneath the sea bed, and in others at great elevations, although the vegetation from which it was formed grew near water and at low altitudes.

Rock-salt, one of the necessities of life, mined inland in many places, as in Cheshire, is simply salt left when sea water evaporates. Thus, in gulfs and places along coasts which became separated from the sea by sand-banks, sea water evaporated, leaving layers of salt crystals. Subsequently, the sea flooded these places again, and again the water evaporated, leaving more salt. This process, repeated many times, resulted in beds of pure salt, sometimes 100 feet thick, which



By permission of *A. E. Smith, Commercial Photographer, London*

MICROSCOPIC SHELLS

The upper photograph shows the actual size of the microscope slide and the group of Foraminifera below the circular cover-glass. The central photograph shows a few of these objects magnified, while the third photograph shows a single object greatly magnified.

Photo Frith

A Wonderful Result of Prolonged Chemical Action

This striking array of stalactites and stalagmites is found in one of the caves at Cheddar, in Somerset. These icicle or pillar growths consist of chalk (carbonate of lime) extracted by percolating water from the limestone rocks above the cave.

were eventually covered by mud and sand. Beneath the beds of salt, there are ripple marks on the solid rock, such as may be seen on firm sand on the seashore to-day. In Abyssinia there is an oval-shaped lake measuring 7 miles across. Half the bed of this lake is dry and consists of dazzling white sea salt.

How can all these apparent contradictions be accounted for ?

Between the downward pressure of the Earth's crust, due to its weight, and the gases within, there is constant action and reaction. If the World were solid and of the same temperature throughout, as at the surface, we might imagine that there would be equilibrium. But, through every active volcano and every hot spring, heat is constantly escaping. (The heat derived from the Sun's rays does not affect the Earth to a greater depth than about 100 feet.)

Now, the escape of heat and gases tends to reduce the internal pressure, and enables the crust to close in further. As it thickened, it offered more and more resistance to bending, and the radius of the curves became greater. Moreover, the weight of the land already elevated was such that, when fresh curving took place, it was easier for the crust to rise beneath the sea. Then, as the ocean beds rose, the land sank downward. As the sea beds curved upward, waves and currents washed off much of the upper layers of ooze with which they were covered, and as they rose above water-level, wind and rain continued the work. Nevertheless, slow as it was, the rise was more rapid

than denudation, with the consequence that hundreds of thousands of square miles of ocean beds were lifted thousands of feet higher than the sea, and formed new continents. The tops of what were once sea beds slowly split, and granite and gneiss, in vast masses, were extruded, forming great mountain chains. And as these immense masses were elevated, the old land sank and the ocean waters receded over it, forming new seas.

Still the work of disintegration and wearing down continued. Rain falling over the new land and running down the slopes wore away channels, that became deeper and wider and formed rivers. Waves beat upon the new coasts, undermining them and causing masses to fall, these being torn about and washed out flat into strata again. The Sun's rays, air, wind and water denuded the new lands of their softer materials, laying bare metamorphic rock and granite, to be disintegrated and worn away in future ages. By such mighty upheavals our present land and mountains were formed.

Thus we have the explanation of sea shells found 18,000 feet high in the Himalaya mountains; of sea-worn pebbles on heights; and of great hills of chalk consisting of the remains of microscopic deep-sea creatures.

So slow are those movements that, with few exceptions, a lifetime is not long enough in which to detect any difference. Nevertheless, in certain parts of the World they can be measured. On the shores

of the Baltic Sea the coast is known to be several feet higher above sea-level than it was a hundred years ago.

When we consider the series of stupendous operations by which the World was created and its surface formed, transformed and reformed many times into its present condition, it is difficult indeed to think of one of them as more miraculous than another. Man has truly been given dominion over all other living things on the Earth, but nothing he can do arrests for one moment those vast operations of Nature.

CHAPTER IX

NATURE'S FORCES

IT may be asked, if the deepest hole ever bored into the Earth is little more than a mile, how geologists know the nature of the Earth's crust down to a depth of twenty miles or more ; and how they know that it crumpled and curved up and down as described.

The materials of which stratified rocks consist were originally deposited in more or less horizontal layers, as the result of the levelling action of water. But when, in a given locality, the Earth's crust was forced upward, the strata curved (Fig. 1) and finally changed from a horizontal to an almost vertical position, so that by traversing such ground, we find in succession the edges of the different strata, once at great depths, now more or less exposed to view. Rocks once at a depth of many miles are thus laid bare and can be examined by removing the surface soil.

In some cases, as in the Andes, the tops of the curves split, and subterranean fires burst through them, forming volcanoes. In other places, the mountainous mass slowly sagged over on one side, until it lay flat : this is known as " folding." The Appalachian mountains are an extraordinary instance of

double folding: ranges of hills were forced upward and tilted until one hill lay flat upon another, exposing the edges of the strata twice over.

In ages to come, when the present ocean beds have been lifted in this manner, and existing continents are submerged, geologists may make further discoveries which will enable them to add to their records: unfortunately, we shall not be witnesses.

Sometimes strata are found sheared right through. These breaks in continuity are known as "faults," and cause earthquakes when they occur. In other cases they are thrown into great disorder where volcanoes have burst through and deposited beds of ashes and lava.

At one time it was not understood why strata containing fresh-water shells are sometimes found below those containing sea shells. The explanation is that in the estuaries of many rivers fresh-water shells were deposited over considerable areas, together with mud brought down by the rivers. Great deltas were thus formed, and in time the rivers changed their beds and found new outlets to the sea. In the course of ages, the deltas sank to lower levels, and the sea, invading the district, deposited marine shells, forming strata over the fresh-water deposits. In course of time rivers again flowed over the deposits, and finally, the whole area of alternating strata was raised to great elevations by movements of the Earth's crust.

Interesting calculations have been made as to how

long it would take for the whole of the present dry land to be worn away level with the sea, supposing that there were no counteracting influences at work, so that the World would be covered with water. It is estimated that this would take from 7 to 12 million years. But opposed to the constant denuding and levelling action of water is that persistant upward and downward curvature that must continue until the Earth's crust is too thick to bend any more.

It is a popular error to suppose that Nature's principal means of wearing away the land is erosion by the sea. Great as that means is, it is only one, and not the most important method. The fall of a great mass of cliff, weighing many thousands of tons, is impressive chiefly because of its suddenness, but it must be remembered that it is the result of many years' work. If, instead of falling all at once, the same mass were to be uniformly worn away, the rate of erosion would be imperceptible.

In describing the Earth's crust, geologists include water and the atmosphere enveloping the World. There is a very good reason for this. Parts of the crust are impregnated with water, some of which emerges and evaporates, and some of which issues from volcanoes as steam. Again, water conveys gases to and fro between the air and the Earth. Finally, oxygen and other gases constitute a great proportion of solids as well as of water and air. The consequence is, that part of a rock may at another time constitute an ingredient of water or of air, and therefore, from

a scientific point of view, it is essential to regard air and water as part of the Earth's crust.

The envelope of gases round the World is called the atmosphere, and consists principally of a mixture of oxygen and nitrogen with an admixture of other gases; also water vapour and whatever else the air carries in suspension. Water is known as the hydrosphere, and includes whatever it may carry in solution, such as salts and acids. The solid portion is called the lithosphere.

The highest mountains are about $5\frac{3}{4}$ miles above sea-level, and the greatest depth of the ocean is about the same. But the average height of the dry land is 2,200 feet, whereas the average depth of the seas is 12,600 feet. Again, the area of dry land is 55,000,000 square miles, whilst that of water is more than $2\frac{1}{2}$ times as much: consequently, the volume of water is nearly 15 times greater than the bulk of land.

If we take air, water and solids together, of the Earth's crust (so far as we know it) almost exactly one half consists of oxygen gas, and one quarter of the mineral silicon.

Of solids, out of every hundred parts, about $47\frac{1}{4}$ consist of oxygen (combined with other elements), $27\frac{1}{4}$ of silicon, $7\frac{3}{4}$ of aluminium, $5\frac{1}{2}$ of iron, and the remaining $12\frac{1}{4}$ parts of a great variety of gases, metals and other minerals in small proportions.

In 100 parts of water there are about $85\frac{3}{4}$ parts of oxygen and $10\frac{1}{2}$ of hydrogen in combination, and $3\frac{3}{4}$ parts of various other ingredients in solution.

The atmosphere consists of a mixture of about $20\frac{1}{2}$ parts of oxygen, 77 of nitrogen and $2\frac{1}{2}$ parts of various other gases, dust and moisture.

Fig. 1.—The Earth's Crust

If the average thickness of the Earth's crust were, say, 200 miles, this diagram illustrates the proportion of such a thickness to the diameter: the unevenness of the outer line representing the highest mountains and deepest oceans.

Although our knowledge of the Earth's crust is considerable, how little it tells us of the structure of the whole World will be understood by a glance at

GLACIERS ON THE NORTHERN FLANK OF MONT BLANC

This illustrates a snowfield, the formation of glaciers, and their erosive action on the mountain rock. As the snow accumulates, its weight compresses the lower portions into rivers of ice, which slide slowly down, wearing immense grooves in the solid rock.

By courtesy of J. Parker, Esq.

Fig. 1. If the circle represents the size of the World, then the thickness of the circular line represents the Earth's crust to a depth of 200 miles. The highest mountains and deepest seas, if shown on the circle, would only appear as slight irregularities of the black line. Sir Robert Ball once made the following comparison: supposing a wet football to represent the Earth, the film of moisture may be compared with the oceans and other water on the Earth's surface; and if all the water in the World were to disappear, it would correspond to wiping the football dry!

CHAPTER X

AVALANCHES, GLACIERS AND ICEBERGS

IN mountainous districts, masses of snow collected around the crests of high peaks, losing their hold as the lower extremities melt, suddenly detach themselves and slide down the slopes at a great speed, carrying with them quantities of earth and rocks, and sometimes destroying whole villages in their path. These sudden descents of snow are called avalanches.

Landslides may be described as avalanches of earth, rocks and debris, and in some cases are the result of water undermining the foot of a slope. The loose materials, of which the slope consists, take what is known as their "angle of repose," and when the foot of the slope is worn away, the support at the lower extremity being removed, the whole mass slides downward. Landslides also occur as the result of materials becoming loosened by rain or disintegrated by frost.

Snow fields are mountainous regions where snow accumulates, and where glaciers originate, sliding slowly down the mountain sides at the rate of from

6 to 15 inches a day. When the lower end reaches a warmer clime, it melts away. In the course of ages a glacier wears mighty grooves in the rock; the snow compressed underneath becomes like a river of solid ice, grinding its way deeper and deeper, breaking off large boulders, carrying them down with it and wearing them smooth as they are forced along the face of the mountain rock. Glaciers sometimes radiate in different directions from high mountains, pursuing a winding course for many miles, and varying in width: when two meet they become compressed into a single bed. In some places occur great cracks and chasms, called crevasses, which may be as much as 700 feet deep; boulders falling down them are frozen into the mass and help to grind the rocky bed to dust and mud. The surface of a glacier is very uneven, and presents the appearance of a rough sea suddenly frozen solid.

As the sides of the valleys are worn away, rocks and mud fall, and accumulate along the edges of glaciers, partly covering the ice, and littering it with debris. When two glaciers come together, the two lines of debris nearest each other also unite, and are carried along the centre, forming what are known as medial moraines; those along the sides, lateral moraines. The lateral moraines increase in size towards the lower extremity as additional debris falls. At the foot of the glacier where the ice melts, these moraines form an immense heap called the terminal moraine.

Although a glacier consists of solid ice, the middle and upper portions travel at a slightly faster rate than the sides and bottom, owing to the friction of the rocks.

Near the lower end of a glacier, where the temperature of the atmosphere reaches the melting point of ice, the surface melts, and water falls down the crevasses and pours out beneath the lower edge in a stream not unlike milk in colour—in fact, it is sometimes called glacier milk—which then flows downwards as a river.

In the course of ages the foot of a glacier may retreat owing to downward movement of the Earth's crust taking place in the locality, or to climatic changes raising the average air temperature. In some cases there is clear evidence that glaciers once extended for much longer distances than they do now.

Glaciers occur in most snow-clad regions of the World. In New Zealand they terminate at levels where luxuriant forests and tree-ferns flourish.

In certain temperate regions, such as North America and Northern Europe, tell-tale boulders are found, some with flat polished sides, others having been scored and scratched in parallel lines, as rocks are scored by glaciers to-day. In some instances it is possible to trace where they were broken off the mountains, hundreds of miles away. These boulders are found in places where there are no existing glaciers.

Now, as the condition of these boulders is to be attributed to the work of glaciers, it follows that, at some remote period, such tracts of country must have been very much colder than they are now, and it was at one time supposed to be a result of the north polar regions having extended farther south than at present. This led to elaborate and complicated theories of a combination of astronomic causes to account for what has been termed the "Glacial Epoch" or "Great Ice Age"; but the strong probability is that the once icebound conditions of the countries in question was simply due to local curvature of the Earth's crust elevating certain tracts above the snow-line. If this explanation be correct, we might as well speak of a present Ice Age because there are glaciers to-day, as talk of a past Glacial Epoch. But let us consider this further.

The greater the altitude, the lower the temperature becomes, until a level is reached at which snow never melts, for the simple reason that there the temperature is always at or below freezing-point. When ocean beds were elevated, large tracts of land rose to great heights, and big areas, now quite habitable, became covered with ice and snow, as some districts are to-day. In course of time a lowering of the general level of such localities took place. If such astronomic causes as the precession of the equinoxes accounted for the glaciated condition of the localities in question, then (as Dr. Lowell contended) all glaciers might be expected to have travelled towards the equator—i.e.

towards warmer climes—yet in fact they were apparently impartial in the matter of direction, for, in the northern hemisphere, some pursued a northerly course, contrary to the deduction from astronomic reasoning that they all ought to have travelled southwards!

We used to be told that after the "Glacial Epoch" there was a "Pluvial Period"—a period of great wetness—and that it followed when all the snow of the Ice Age melted. No doubt the sudden melting of vast quantities of snow would cause heavy floods in the countries concerned; but there is no reason to suppose that the snow did melt suddenly.

Where glaciers melt at their lower ends, rivers begin, washing away quantities of the debris brought down. This debris collected in some places and served as natural dams across the old glacier beds, and thus many lakes were formed.

When glaciers end in the sea, their lower extremities break off and float away as icebergs, dropping masses of rock, sand and mud as they melt. In the Arctic and Antarctic regions the land is covered by fields and mountains of ice. The land slopes towards the sea and these masses are in the nature of colossal glaciers covering the whole area, which gradually slide down into the ocean, and, ice being lighter than water, the projecting ends are broken off by the upward pressure, and float southward. In the Antarctic regions glaciers are on the grandest scale.

As they advance into the sea, they present the appearance of mountainous cliffs of ice, from which masses, the size of an English county, break off and floats northwards, gradually melting until they disappear. It is supposed that the fractures are caused partly by volcanic or earthquake shocks.

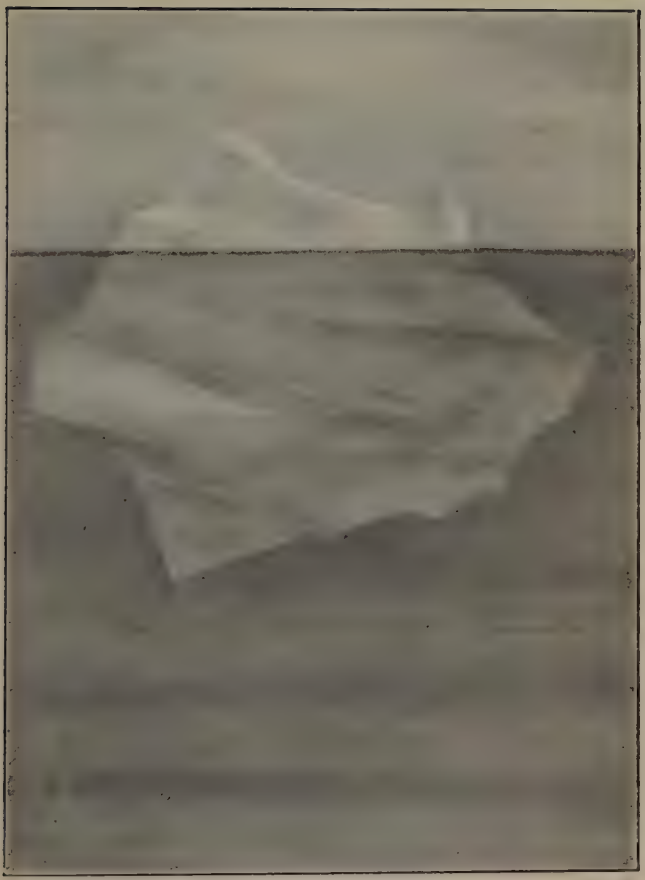
Icebergs vary in size from a few yards in width and height to floating mountains many miles long, and sometimes as high as 1500 feet above the water-level. Even that does not give a true impression of their magnitude; for the mass above water-level is only about one-eighth part of an iceberg, so that its volume is actually 8 times greater than the visible portion. Very large Arctic bergs often run aground in comparatively shallow water before reaching the open ocean, and there slowly melt and drop great quantities of rock and clay torn off and ground out of the land before breaking away, and frozen within them. The Greenland bank was largely formed of materials dropped by melting icebergs. It is fortunate that this happens, otherwise they might float long distances south before melting, and constitute a much more serious menace to shipping on the great trade routes than those now met with. Even as it is, vessels are sometimes almost surrounded by them and have to stop their engines for hours at a stretch.

After partially melting and becoming top-heavy, icebergs frequently turn upside down. On a certain occasion, one broke into three pieces near a vessel;

one piece plunged beneath the ship, lifting her 5 feet and almost capsizing her. Icebergs have been known to drift nearly as far south as Cape Hatteras. In the year 1893, a vessel named the "Wasdale" found herself in a bay within an almost continuous ring of them. The bay measured 20 miles long by 10 miles wide, and 4 miles wide at the mouth. Once over 1,000 bergs were passed in a distance of 200 miles. Another vessel sailed round one which was said to measure 600 miles in circumference. Small blocks of ice, the unmelted remains of icebergs, have been seen within 1,850 miles of the equator.

It is a common error to suppose that icebergs are always graceful, glittering peaks. Many, indeed, are so covered with rocks and earthy matter as to appear like, and be mistaken for, land, with the consequence that mariners have actually reported them as islands dangerous to navigation. In some cases, volcanic rocks have been found upon them. A dangerous feature is that many of them are very much wider and longer beneath the water than above, so that a ship is liable to strike one while apparently some distance from it, the most notable instance on record being the sinking of the "Titanic" with the loss of nearly 2,000 lives.

Many interesting anecdotes could be related of adventures with icebergs. Polar animals are sometimes transported by them, and have been seen in a state of terror at the doom which they instinctively knew awaited them. In the year 1851, not far



AN ICEBERG, SHOWING THE SECTION UNDER WATER

For every cubic foot of ice above water there are seven cubic feet below.

A Blue Whale

from Newfoundland, a great berg with field-ice round it was seen, and upon it were two three-masted ships, high out of the water. In the year 1894 another was sighted on which were the bodies of five dead men.

CHAPTER XI

THE EARTH'S MOVEMENTS

LET us in this chapter touch upon a few astronomical considerations, some of which are not generally familiar. (It is assumed that readers are conversant with such elementary matters as proofs that the World is round, which may be found in any good geography.)

If we throw a stone, the moment it leaves our hand it is acted upon by three forces ; the force with which it is thrown, the resistance of the air trying to stop it, and the force of gravity drawing it towards the Earth. The consequence is that it describes a curve and falls. If we imagine that the Earth would not attract the stone, the friction of the air would gradually stop it and it would remain suspended. But if the Earth did not attract it, and there were no air to resist its passage, the stone would continue to travel for an indefinite time and distance, in the direction in which it was thrown.

The influence exerted by the Earth on the Moon is similar : the Moon is always trying to speed away at a tangent into space, but is prevented from so doing by the Earth's attraction. The result is a compromise,

and the Moon travels round the Earth. Similarly, all the planets are tending to fly away into space, but are prevented by the attraction of their lord and master, the Sun. This is at least a partial explanation of why the various worlds of a solar system continue in their respective orbits.

It is commonly stated that the Earth rotates on its axis once every twenty-four hours ; but, like a great many statements that are made about a great many other things, that is putting the case the wrong way about. What happens is that the Earth rotates on its axis, and we divide the time it takes to do so into what we call hours, an hour being a purely arbitrary subdivision of time that enables us to decide how much of the day and night shall be devoted to work, recreation or sleep. As a matter of fact, like English currency and the English system of weights and measures, it is not the best division for purposes of computation ; it would have been more convenient to divide the day into 36 hours, so that each hour might represent the time taken for 10 degrees of the Earth's surface to rotate about its axis.

If we hold a ball—or better still—a globe of the World, up to the light, the half nearer the light is illuminated and the other half is in shadow. If we turn the ball or globe round, each portion in turn is exposed to the light. So it is with the World and the Sun. As the Earth rotates, it presents each part of its surface successively towards the Sun. That is what causes day and night.

In addition to rotating on its axis, the World travels in an almost circular path round the Sun, this path being known as its orbit. While describing one such circle, the Earth rotates about $365\frac{1}{4}$ times on its axis. the time it takes to describe a complete revolution we call a year, and it follows that there are $365\frac{1}{4}$ days in a year.

The axis of the Earth is an imaginary straight line passing through its centre from the north to the south pole. The equator is an imaginary line drawn round the Earth at right angles to the axis at an equal distance, at all points, from each of the poles. Imagine an exceedingly thin disc passing right through the centre of the World, so that its edges cut through the equator: such a disc would be known as the equatorial plane.

If the Earth's equatorial plane were always at such an angle that, if extended far enough, it would cut the Sun in half, there would be no seasons, for the Sun's rays would always have the greatest power on the line of the equator. Instead of this, the equatorial plane is at an angle of $23\frac{1}{2}$ degrees to the orbital plane, so that for six months of the year the rays shine more strongly north of the equator in one half of the World, and for the other six months with greater power south of the equator in the other half of the World. The consequence is that the direct rays of the Sun fall upon the Earth on a line which passes round the World at an angle to the equator, and crosses it at two points. This imaginary path of the Sun is called the ecliptic.

In spring and autumn, the Sun is directly overhead at these points of intersection, and for some weeks before and after, while summer conditions are changing of those of winter, and vice versa, we experience what are known as equinoctial gales, which result from alterations in the direction of warm and cold air and ocean currents.

In addition to causing the seasons, the angle of the ecliptic to the equator accounts for the difference between the length of days and nights. If we examine a globe of the World on which the line of the ecliptic is marked, all this will be readily understood.

The Earth's orbit is not a perfect circle, although nearly so. It is an ellipse. The Sun is not always in the centre of the ellipse; sometimes it is a little on one side of the centre, sometimes on the other, with the consequence that the distance of the Earth from the Sun varies, not only by reason of its elliptical orbit, but also on account of the Sun's varying position in the ellipse. It is believed that it is not the Sun that changes its position, but that it is the Earth's orbit which varies: in other words, the Earth does not always travel in exactly the same orbit. In the course of hundreds of thousands of years its path varies from something approximating to a circle to a more elongated ellipse. This change is due to the effects of gravitation.

Each of the planets varies in its relative position to the Earth, being sometimes nearer and sometimes farther away. The nearer a planet, and the greater

its mass, the greater the attractive pull it exerts on the Earth ; and if two or more are in comparatively close proximity with each other and the Earth at the same time, the pull increases in strength. It is supposed that about every 200,000 years the planets all reach positions where they exert their maximum attraction in one direction, and then gradually reach positions where their combined attraction is greatest in another.

A fourth movement is not generally known. When a top is spinning, but is not quite upright, its axis leans out of the vertical, so that a pin stuck in the centre slowly describes the figure of a truncated cone, the head of the pin describing a circle. That is what the Earth is doing, and it is believed that it takes more than 25,000 years to complete the circle : this is known as the " precession of the equinoxes."

A fifth movement is common to the whole of our solar system. Whilst the Earth and other planets rotate on their axes and circle round the Sun, the complete system is believed to be speeding through space towards a star called Vega, at a speed of 11 miles a second. Here, however, we are applying a local measurement to time and motion in space and, consequently, find ourselves up against an elementary proposition in relativity. This speed of 11 miles a second is supposed to be towards a stationary object—an admitted impossibility. On the other hand, if we gauge our speed relatively to an object retreating from us at the same rate, we could not say that we

are moving at all. Finally, if we gauge it by another object moving towards us, the relative speed of approach may be 22 miles a second, more or less, according to the speed of the other body.

Fig. 2.—The Orbit of the Solar System

Whilst the Earth rotates on its axis and revolves round the Sun, the whole solar system moves through space in an immense orbit of its own. The orbit of a solar system, however, is not necessarily in the plane indicated, but may be at any angle to its own planetary orbit.

The World being nearly 25,000 miles in circumference, since it rotates once every 24 hours, its peripheral speed at the equator is slightly more

than 1,000 miles an hour. It is (on an average) about 93,000,000 miles from the Sun, so that its orbit measures, roughly, 584,000,000 miles. Since it travels this distance in a year, it follows that it is racing round the Sun at the rate of about 1,100 miles a minute, while travelling with the whole solar system through space at 660 miles a minute.

It is common knowledge that the attraction of the Moon and Sun causes ocean tides. But it is not so well known that they also cause a tidal wave in the solid crust of the Earth.

Owing to the speed of its revolution, the particles forming the Earth's crust tend to fly off by centrifugal force, this tendency, however, being counterbalanced by the force of gravitation which holds the particles together. Nevertheless, the combined effect of centrifugal and tidal forces is to drag the World to some extent out of shape, so that instead of being a perfect globe, it is slightly flattened at the poles, its diameter on the equator being some 27 miles greater than between the north and south poles.

Taking a walk on terra firma, or lying quietly in bed, it is difficult to believe that our globe consists of a relatively thin shell containing over 200,000,000,000 cubic miles of scorching gases; that the shell is cracked, broken and bulged all over; and that in that condition it is going through such a combination of movements at speeds almost beyond comprehension.

The subject of motion in space is of such interest that a short digression is here permissible.

Let the reader imagine himself to be seated in the centre of a smoothly rotating disc, his legs extended and his feet towards the edge : in such a position he would be conscious of the fact that his feet are moving round at a greater speed than his body. But if the disc were at such a level that he could see nothing beyond its edge, he would not realize the fact that it is moving. If, however, the disc were caused to rotate with sufficient rapidity, he would become conscious of centrifugal force at work tending to make him slide away towards the edge.

Let us next suppose that you and I are both on the disc, the edge of which is moving round at a speed of, say, 5 feet per second, and that from a point on its edge you draw a line, A—B, one inch long towards the centre, taking one second to do so. During the same second, leaning over the edge of the disc, I draw a line, C—D, but on the ground, and from a point one inch distant, to the edge of the disc. We shall then have drawn two lines, A—B and C—D. Yours will measure one inch on the disc, mine will measure a little more than 60 inches on the ground, although each of us has only apparently moved his pencil one inch. You might be disposed to admit that the line I drew represents the real movement of my pencil-point, but for my part, I must admit that the line I drew, although 60 times as long as yours, is only a tiny, visible portion of an immense and far more

complicated line which my pencil-point described in space in that single second of time.

In drawing our lines towards the centre of the disc, each of us would have exerted the same amount of energy to overcome centrifugal force, so that, ignoring the friction of the pencils (which may be regarded as negligible), you would have exerted as much force in drawing your one inch line as I should have exerted in drawing a line 5 feet long.

It appears a simple enough proposition to take pencil, ruler and paper and to draw a line an inch long. Yet, when the World's movements are taken into account, we find that our pencil-point in one second of time has described an enormous and complicated curve in space.

Let the reader seat himself at a table and draw a " straight " line from east to west. We will suppose that it takes one second to draw it from a point A to a point B.

Since the World rotates on its axis once every twenty-four hours, its peripheral speed at the equator is about 1,000 miles an hour, the speed of rotation diminishing to zero at the poles. Let us say that at a certain latitude in England the peripheral speed is 820 miles an hour from west to east. That means to say that any point at that latitude travels through space round the World's axis at the rate of about 400 yards per second from west to east. Therefore, whilst drawing your line from east to west, the points A and B will move 400 yards towards the east, and

consequently the pencil will not really travel from east to west at all, for whilst moving from A to B in one second, the point of the pencil will travel 400 yards in a curved line, through space from west to east (minus the length of the line drawn).

But that is not all. In its orbit the Earth revolves round the Sun at a speed of about 19 miles a second, so that, in addition to describing the curved line of 400 yards, the pencil-point moves through 19 miles in another curved line of a radius of 93,000,000 miles. The resultant direction is, of course, a compromise between the two.

Still, that is not all. Since the solar system as a whole moves through space at a speed of about 11 miles a second, whilst drawing your line, the point of the pencil moves 400 yards in one direction, 19 miles in another direction, and 11 miles in still another direction.

One might go on quoting instances of other movements. For example, the presumption is that the stellar universe, to which our solar system belongs, is in motion as a whole.

Thus, the line through space traced by the pencil-point, if it could be viewed by an independent observer, would constitute a series of great curves of the greatest complexity. Yet, if instead of viewing the line from an independent standpoint in space, the observer were always moving parallel to it, it would no longer appear to him as a complicated curve : for all he could tell, it might be a straight line !

It is equally true that every point which we call a fixed point on the Earth is for ever describing a curve, like the convolutions, on an inconceivably vast scale, of a writhing snake—its tortuous journey already performed lost in the past, its new position at each instant of time indicating its existence in space.

CHAPTER XII

TIME

MANY people, if asked to define Time, would not regard it as an insuperable task. Yet, of all the unfathomable mysteries which the finite mind ever set itself to consider, none is more baffling or elusive. In the first place, it is as difficult to imagine the beginning and the end of Time as to grasp the idea of Eternity. We speak of a year as the time occupied by the Earth in its orbit, and define a year as $365\frac{1}{4}$ days, during each of which the Earth completes one revolution about its axis: this is, of course, a convenient and indeed, the only means by which the affairs of mankind can be ordered, but upon further investigation, we find that a day and a night are not a measure of Time at all.

Imagine an aeroplane capable of a speed equal to the peripheral speed of the Earth, and suppose it to start at dawn and to travel in an easterly direction round the world. In 24 hours it would arrive (at dawn) at the point from which it started, *but in the meantime would have passed through two days and two nights*, having completed two revolutions about the Earth's axis while the Earth completed one.

If, on the other hand, it were to travel in a westerly

direction, the pilot would experience neither day nor night: to him, it would be dawn all the time; yet in 24 hours, he would arrive where he started from without the day having advanced by a minute, although it would be the next day.

Again, in attempting to gauge Time by the year, or even by the stars, there is no proof that we are measuring Time at all. The rate of movement of the celestial bodies varies year by year. Astronomers only profess to have proved a small fraction of the precession of the equinoxes. Our chronometers, clocks and watches are set to record so many hours, minutes and seconds a day or a year; they are merely mechanical instruments recording movements, and afford no evidence that the length of any year is the same as that of another. Supposing that every year were one minute shorter than the preceding one, then, 525,959 years hence, one year would pass whilst our present-day clocks recorded one minute.

Again, it is known that our days increase in length relatively to the year, and that in time to come a day will be equal to a year, just as Mercury's day is now equal to his year. But the expressions "day" and "year" will both be meaningless then, for one half of the World will always face the Sun, and the other half will be in perpetual darkness. It will always be day or night, or twilight, according to the point of observation. It will be impossible to divide a year into days, or days into hours and minutes. There will be no seasons, for it will always be glaring sunshine

on one side of the Earth, and dark winter on the other.

Pursuing the subject to its logical conclusion, it is clear that the length of a minute, hour, day or year, is a varying quantity, and is a purely relative measure of Time. One year of the planet Neptune is equal to 165 of our years, and a year of the planet Mercury only equal to 88 of our days.

We speak of "the heavy hand of Time" upon a man, or say that he is aged because of his years; but has that any connection with Time? Is it not rather that so many seasons, so many days and nights, so many rounds of tribulation—labour, anxiety, illness, shock, indulgence or privation, have effected changes in him that we call "old age"? Even as we commonly think of age, we know it to be relative. Some people die young, others live to a great age. One man is vigorous and strong at 70 and may live to 100; another, perhaps originally gifted with the same physical attributes, is decrepit and bedridden, or dies at 60, showing that senile decay and death may be due to causes other than Time. There is food for reflection in the old fairy story, "The Sleeping Beauty." Imagine it to be possible for a young and perfectly healthy person of 20 to pass into a trance for 100 years, during which all his physical and mental faculties cease to operate. At the end of the 100 years, it is far more conceivable that he would wake in the same condition than that he would have degenerated into an infirm old man. On the other hand,

if we were to place him in dark and solitary confinement and only allow him such necessaries as would maintain life, if he lived five years, what should we expect him to look like at best? His hair would be white, he would be old and blind. Such effects are known to have been produced by such means.

From another point of view Time, of course, is connected with Egoism—the relativity of everything to personal existence. What is the gauge of Time by the inmates of a madhouse? How long would five years of dark and solitary confinement seem to a victim? I sit down at nine o'clock to write, and can scarcely believe that an hour has passed when the hands of the clock point to ten. Yet how long has it appeared to others anxiously awaiting the crisis in a dangerous illness; to a sufferer in agony—even to those who have been "killing time"? The hour that has passed so quickly to me has seemed an age to them, and the cause of its apparent duration may have taken days, months or years off their lives.

Time, like Space, cannot be measured, and eludes our comprehension. It is but a "parenthesis in Eternity."

CHAPTER XIII

THE SUN AND ITS INFLUENCE

CONSIDERING that we are indebted to the Sun for our very existence, it will not be out of place to devote a chapter to a few elementary facts about our great luminary.

Its average distance from the Earth is 93,000,000 miles; but since the World's orbit is not a perfect circle, but slightly elliptical, this distance varies about 2,000,000 miles either way. After traversing this vast distance, the Sun's rays strike the envelope of air surrounding the World, penetrating hundreds of miles of atmosphere and finally reaching the Earth's surface after losing probably more than half their power. That they do so is fortunate for us in a double sense. If it were not for the protecting blanket of atmosphere, the rays would strike the Earth with more than twice their present intensity, but, as the heat would instantly be dissipated in space, the World would be covered with ice and snow, despite the fact that during the day the surface would be exposed to the full glare of the Sun. For the atmosphere not only partially absorbs its rays, and reduces the intensity of the Sun's power, but serves to

prevent too sudden an escape of heat from the Earth's surface.

For æons its influence has been exerted, as it is exerted to-day, and its rays, upon striking the Earth, set up vibration and motion of the molecules of which all matter consists.

We are accustomed to think of the Sun merely as an agent for warming and lighting the Earth, but we are indebted to it for more than that, for it is partly due to its effect that we possess such sources of artificial light, heat and power, as coal and oil. But for its influence, vegetation would not have flourished as it did in the Carboniferous period, and that process would not have taken place by which, millions of years ago, forests grew, were buried, and turned into coal, forming vast reserves of fuel in many parts of the World.

Without the Sun, there would be almost entire absence of heat, or absolute cold—cold so fearful that imagination refuses to grasp what it means—no life could exist, and one can only think of the oceans as frozen solid and indistinguishable from the land; for we know that in the Arctic regions, where the influence of the Sun does not directly penetrate, similar, although more moderate conditions obtain.

The total heat derived by the Earth from the Sun in a year has been estimated as sufficient to melt a layer of ice 114 feet thick over the whole surface of the World—an average of $3\frac{3}{4}$ inches a day; yet this only

represents 1/2,381,000,000th part of its heating power ! Some idea of this may be gained from the following comparison. If we place a bead, the size of a pin's head, at a distance of 15 feet from an ordinary electric lamp, and imagine the lamp to represent the Sun, and the bead the World, then the amount of light received by the bead from the lamp is in about the same proportion as that received by the World from the Sun. Similarly, minute proportions of the Sun's rays reach the other planets of our solar system, and the rest is dissipated in space. At first sight, this appears like stupendous waste on the part of Nature, but it is not given to us to comprehend the ultimate purpose of events in the universe. Our little World—the Sun itself—is but a speck in space ; and our puny minds, groping in the dark, are lost in contemplation even of the little that is known.

Imagine the World to be suddenly deprived of all the older products of the Sun's influence : civilization would be held up, for there would not be an ounce of coal, a drop of oil, or a block of wood for fuel : railways and all means of locomotion would be useless ; not an engine, factory or workshop could be run ; no food could be cooked or fires lit ; no clothes could be made, and if it were possible to live at all, in a short time we should become savages—perhaps cannibals. Thus, we see that artificial heat and light, upon which civilization depends, are the fruits of the Sun's beneficent influence in the past.

If its heat could be utilized, it would provide far greater energy than is produced by artificial means. We know that, by focussing its rays, one can light a pipe or set fire to inflammable material. On one occasion, during the construction of a breakwater, men were working 30 feet below water-level in diving-bells in which lenses were fixed to let through the light. One day, the Sun's rays, focussed by these lenses, set fire to a workman's clothes, after passing through 30 feet of water! Experiments have proved that it is possible to generate steam in a boiler by focussing the Sun's rays upon it: a plant for this purpose (a model of which may be seen in the British Museum) was actually erected in Egypt.

Man delves and bores for the products of the Sun's influence, matured for his use through past ages; brings them to the surface and applies them in the production of heat, by means of which he constructs and drives his engines and machinery, propels ships and vehicles, destroys his fellow-men, soars in the air, gropes beneath the waves, generates light and electricity and produces those works of which civilization is so proud. And in so doing, wastes an enormous proportion of what it has taken Nature millions of years to prepare for his use.

Whether it be in the desert, where air ascends from scorching sands and gives rise to wind; or on the borders of the Arctic regions, where mountains and fields of ice break loose, heat derived

from the Sun is Nature's prime moving force on Earth.

The nature of the Sun's ray is a subject of deep interest. Invisible rays at one end of the visible portion of the spectrum produce the greatest heat, while the yellow rays yield the greatest light. At the other end of the spectrum are invisible ultra-violet rays that produce chemical effects, as for instance, upon photographic plates. If we stand in the Sun on a hot day, we may think that its rays are themselves hot; yet, strange to say, that is not so. The action of the rays upon the molecules of matter causes the molecules to move at incredible speeds. In so moving, they strike each other, and the result of their countless collisions is the production of heat.

When the ground, or the surface of the sea, is heated, the air is warmed and rises, cooler air takes its place, and so we get wind. Dry air in contact with water absorbs moisture that is carried by wind and dispersed over the World, cleansing and purifying air, earth and sea, and setting up other natural forces as essential to life and health as heat itself.

The Sun also provides us with colour. Sunlight appears white, or nearly white, but really consists of many different colours. If we take a glass prism and hold it in the Sun's rays, in passing through it they are divided, so that if directed on to a shaded surface their separate, beautiful colours may be seen. This

splitting up of light is known as refraction. When the Sun's rays are shed upon an object, some are absorbed by it, that is to say, that the rays penetrate it, while others are reflected from it. When it absorbs the blue and yellow rays and reflects the red rays, the object is called red. Another substance absorbs red and yellow rays and reflects blue, and we call that

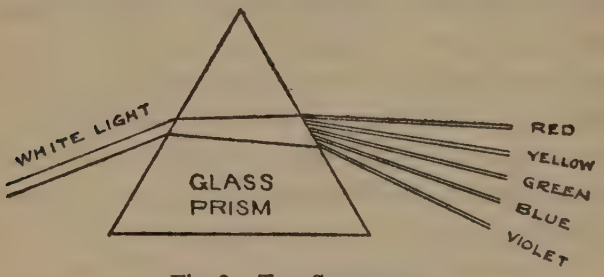


Fig. 3.—The Spectrum

When a bead of light enters a glass prism, it is divided into its component colour rays which upon leaving the opposite face of the prism separate so that, if directed on to a shaded surface, they give the full spectrum of visible light, ranging from red to violet through all the colours of the rainbow. For the purpose of simplicity, the different colour rays are shown separately, but in fact they merge imperceptibly.

substance blue. But the colour in every case is that of the reflected rays of light. It follows then that, but for the Sun, there would be no such thing as colour.

Again, the natural beauty that surrounds us, whether it be that of hill or dale, mountain or lake, land or seascape, river or waterfall, is largely due to the Sun's influence.

The Sun is 866,000 miles in diameter, and more than

1,000,000 times the size of the Earth, but not nearly so dense ; with the consequence that, although so much larger, it only weighs about 330,000 times more than the Earth. Since light travels at a speed of 186,000 miles a second, it follows that light from the Sun takes just over 8 minutes to reach the World. Owing to the Earth's revolution, the result is rather curious, for, if we look at the Sun through a piece of smoked glass, say, in Salisbury, light rays are seen that left it 8 minutes before in the direction of London. In other words, none of the Sun's rays reaches its original goal because, during the 8 minutes' journey through space, that goal has moved round and receives, instead, rays that were directed ahead of it 8 minutes earlier.

The Sun rotates on its axis once in about every 25½ days (Lowell gives 28 days). That is proved by dark patches on its surface, called sunspots, that appear on one side, pass across it in about 12 to 13 days, disappear on the other side and reappear again in another 12 to 13 days. In time they disappear entirely and fresh ones break out. These spots are believed to be enormous gaps in incandescent gases, caused by immense showers of elements that form from vapours far away from the surface and fall into the flaming mass. Or it may be that, in contracting, the pressure on the internal gases as so great as to cause violent explosions. However it may be, these spots are associated with tremendous disturbances on the Sun's surface. When new ones appear, they effect

strange, and sometimes violent fluctuations in the Earth's magnetism.

Surrounding the dark interior is a dense mass of luminous cloud, called the photosphere. Above this is a layer of gas, called the chromosphere, about 6,000 miles thick, from which protuberances rise. These protuberances, best seen during an eclipse of the Sun, are vast flames and jets of fire ; in the year 1880, one was observed 40,000 miles high, which, in an hour and a half, soared up to the stupendous height of 350,000 miles—1½ times as far as the distance between the World and the Moon. When a spot reaches the rim of the Sun, so that it appears partly edge-on, it is seen that the protuberances surround cavities from which, or from near which, the flames emanate.

In the Sun there exists in a gaseous form exactly similar elements to all those that constitute our own World. This is ascertained by astronomers with the spectroscope, an instrument by means of which the rays emitted by different incandescent gases can be split up and their nature ascertained, since each gas possesses its own peculiarity in the matter of colour.

To the Sun's influence we owe everything that makes life possible ; heat, power, light and colour. Without it, there would be darkness, and cold so intense that the very air would liquify and freeze solid. Needless to say, life would be utterly impossible under such conditions, but, supposing it were possible—supposing that we could exist without air and warmth and

light—it would be a life of blindness, of groping in pitch darkness on a slippery World of ice. We should be invisible, cold-blooded animals, devoid of the senses of sight, hearing, smell, taste and feeling.

CHAPTER XIV

THE SEASONS

IT is quite a common mistake to suppose that the difference between summer and winter is caused by the slightly varying distance of the Earth from the Sun. Far from this being the case, our summer occurs when the Earth is at its greatest distance, and winter when it is at its least distance from the Sun, proving that this variation in distance has nothing to do with the seasons.

In Chapter II it was explained that the seasons are due to the World's equatorial plane being at an angle to the plane of the ecliptic.

Now, the Sun's rays are most powerful where the Sun is directly overhead, consequently it is on the line of the ecliptic, and not on the line of the equator, where the greatest heat is experienced. And since half the ecliptic is north of the equator and the other half south, the Sun's heat and light extend further north for six months of the year on one side of the World, and further south for the remaining six months on the other side. This fact will be better appreciated by examining a globe of the World on which the line of the ecliptic is marked.

The vernal or spring equinox occurs on the 22nd

of March, and the autumnal equinox on the 22nd of September. On those dates, the day and night are of equal length, and as the Sun begins then to pass to the

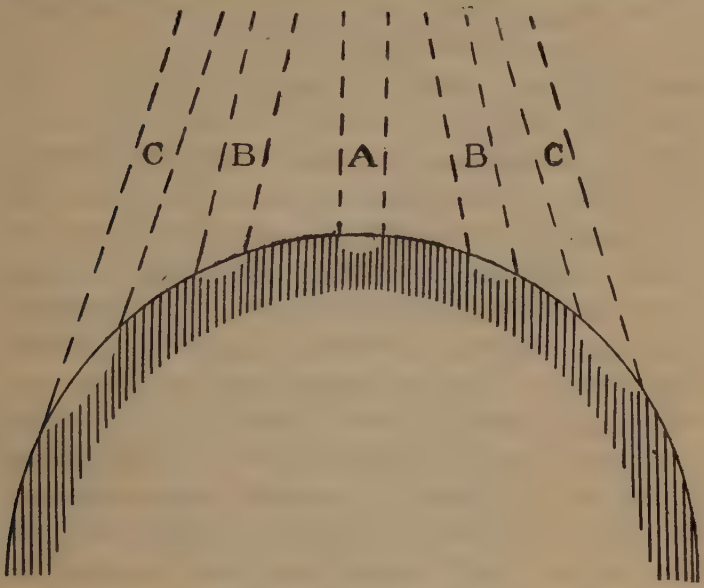


Fig. 4.—The Sun's Rays

Supposing A to represent a circular shaft of the Sun's rays and C another shaft of the same diameter as A: then the number of rays per square foot beneath A is evidently greater than the number per square foot under C. Moreover, the C rays having to pass through a greater thickness of air than the A rays, their power will be further reduced.

other side of the equator, different currents of wind arise and cause what are called equinoctial gales, which last until fresh prevailing winds are established. The Sun only appears directly over the equator where the equatorial plane intersects that of the ecliptic.

The solstices occur when the line of the ecliptic is furthest north or south from the equator. The most northerly position is attained on June 22nd, when it is midsummer in England, and the most southerly position on December 22nd, when it is midwinter in England, but midsummer at the Antipodes—say, in New Zealand. The day is then 18 hours and the night 6 hours long, or vice versa, according to whether it is midsummer or midwinter. In each case, the day is measured from sunrise to sunset, and does not include the light before dawn or after sunset.

It is not generally understood why, when the Sun is overhead, its heat influence is greatest. Fig. 4 explains this. Let us suppose the dotted lines to represent shafts of the Sun's rays upon a portion of the Earth's curved surface. Now, if we consider the shafts as made up into bundles of parallel rays, it will be seen that bundle A of a given width is concentrated over a space vertically beneath the Sun. But as we work round the curve, another bundle B of the same width as A is distributed over a greater width, whilst a bundle C, also of the same width as A, is distributed over a still greater area. The consequence is that the number of A heat rays per square foot of the Earth's surface is much greater than the number of B or C rays, and therefore the temperature is greatest under the A rays.

There is reason for believing that, in the early stages of their careers, the planets rotated from east to west, instead of from west to east as the Earth

does now, and that they gradually turned over on their axes. Neptune still rotates from east to west, and Uranus almost at right angles to his orbit. It is supposed that as ages pass, the equatorial plane of the Earth will approximate more and more nearly to the plane of its orbit. If and when the two coincide, there will be an end to the seasons, and days and nights will be of equal length all the year round. At first sight, that may appear of little importance, but, on further consideration, one feels thankful that such a state of affairs is far ahead, for then the Arctic and Antarctic regions will extend uniformly from the poles, and parts of the World will become uninhabitable. There will be no summer or winter, but regular day and night temperatures in any given latitude, and winds will set in fixed directions, rising from the torrid zones and flowing always towards the poles.

Imagine the monotony of such conditions, were they to be suddenly imposed upon us. The wonderful variety of the seasons that accords so well with the restlessness of human nature, would cease, we should long for the annual change from crisp, winter winds sweeping over the snow-clad country to the exquisite verdure of spring-time : the soft warm breezes and glorious flowers of summer, and the rich colours and sadness of autumn, each emblematic of life.

CHAPTER XV

THE MYSTERY OF COLOUR

THE subject of colour is bound up with that of light and of optics, and as the connection is capable of simple and interesting explanation, it should be understood in order to appreciate the subject-matter of the present chapter.

We speak of the sky as blue, of grass as green, of a geranium as red, of a sheet of paper as white, and so on, but, as a matter of fact, these things are not themselves coloured. (This was partly explained in Chapter XIII, and further explanations will be found in the chapter on Light.)

The reflection of light rays by different substances, in varying proportions, sets up vibrations of the optic nerve of the eye, passing through to the retina which is in the nature of a photographic plate at the back of the eye and from which the brain receives impressions or pictures of objects. Colour, therefore, is not that of the object we are regarding, nor does it exist in our eyes, as we are sometimes told ; it is due to a blending of different rays of light, reflected from the object. This may seem strange at first, because we are apt to think that only polished surfaces can reflect light. But let us take one or two simple cases. When a

white bird is flying, it may appear black. The same is true of aeroplanes and air-ships : sometimes they look almost black, and at other times like burnished metal. Again, a piece of coal may appear like polished silver, according to the angle at which the light rays are reflected. Now, if colour existed in the object itself or in the eye, the same object would not seem black one moment and white the next. A sheet of blank paper in daylight may appear white, but if we take the same sheet into a dark room and direct a red beam of light upon it, it will appear red. In other words, it reflects red rays.

Another familiar illustration is that of transformation scenes and coloured lime-light effects upon the stage : by shedding the light through tinted glass beautiful effects are produced on objects which merely reflect the tinted rays. But the colour reflected is not necessarily the same as that of the light rays producing it. For instance, an object which appears red in sunlight, will, in a dark room, appear nearly black under the rays of a blue light. A rainbow is an instance of the refraction and reflection of the Sun's rays upon striking condensed moisture or falling rain.

Interesting examples of things which apparently change colour are afforded by " shot " silk, and the feathers on a bird's neck. These effects are the result of the varying angles at which the colour rays of light are reflected. The chameleon possesses the power of adapting himself to his surroundings by

movements of his skin that contains different pigments by which the little animal can apparently change his hue. There are some amusing verses on the chameleon describing how two travellers in Arabia discussed his colour. One affirmed that it was green, and the other that it was blue. At last a third traveller joined them, to whom the question was referred :

"Sirs !" cried the umpire, "cease your pother,
The creature's neither one nor t'other,
I caught the animal last night
And viewed it o'er by candle light.
I marked it well—'twas black as jet.
You stare, sirs, but I have him yet,
And can produce him." "Pray, sir, do—
I'll lay my life the thing is blue."
"And I'll be sworn that when you've seen
The reptile you'll pronounce him green."
"Well, then, at once, to ease your doubt,"
Replied the man, "I'll turn him out,
And when before your eyes I've set him,
If you don't find him black—I'll eat him."
He spoke. Then full before their sight,
Produced the beast and, lo !—'twas white.

The fact that light, which appears white, really consists of a variety of colours, is proved by a glass prism (say, one of the triangular pendants from an old-fashioned glass ornament), which, if held up to the Sun, refracts or splits up the light into its component colours. Moonlight is simply the Sun's rays reflected from the surface of the Moon, and a prism splits up the rays into colours similar to those of direct sunlight.

THE GIGANTOSAURUS, THE LARGEST KNOWN ANIMAL THAT COULD LIVE ON LAND

A Diplodocus, which previously held the record for size, and a man are shown for comparison. The largest individual Gigantosaurus is known from a thigh-bone, found in German East Africa; this bone is 11 feet long, and indicates that the animal stood 20 feet high at the shoulder. The corresponding bone in Diplodocus is 3 feet 3 inches long.

A Ceratosaurus, from the Upper Jurassic of Colorado

This reptile was 20 feet long, and is shown attacking the huge Stegosaurus, which stood 11 feet high, and was protected by a double row of bony plates along the back.

Thus we see that colour is in the nature of a sensation, and that its variations depend upon the extent to which light rays are absorbed and reflected by individual substances. When a flower fades and loses its tints it is due to a change taking place in the substance of which it is composed, which causes it to absorb and reflect different light rays from day to day.

Having ascertained the cause and meaning of colour, we may revert to the more convenient (if incorrect) way of regarding it as something which is part of a substance itself.

There are three primary colours, red, yellow and blue, so called because they serve as a basis for all others ; that is to say, that from these three all others can be obtained by mixing pigments in the correct proportion.

By mixing the primary colours, six others may be obtained. Thus, red and yellow make orange ; red and blue make purple, and yellow and blue make green, and from mixtures of these three secondary colours we get brown, grey and others.

Primary Colours.	Secondary Colours.	Tertiary Colours.
Red	Orange	Brown
Yellow	Purple	Grey
Blue	Green	Broken green

Their colouring enables many creatures to adapt themselves to their surroundings and secure protection from enemies. Many instances could be given,

such as that of the green tree frog, which is often difficult to detect even in a vivarium. The stick-insect so closely resembles a twig, and the leaf insect a leaf, that it requires an experienced eye to see one. Certain flat fish, lying on the sand, cannot be seen until they move. In the Arctic regions, the bear and fox are white and almost indistinguishable in the snow, and the camel of the desert takes on the nuance of his surroundings. The zebra is a remarkable instance of natural " camouflage." These are cases of what is known as protective colouring. But colouring in harmony with their surroundings also affords creatures, such as the lion and tiger, opportunities for stealing unperceived upon their prey which would otherwise, by their superior speed, escape them.

In certain instances we find animals, reptiles and insects, with a colouring that contrasts vividly with their environment, but in such cases they possess some natural means of offence rendering them poisonous, or otherwise dangerous or obnoxious to other creatures. Included in these are the wasp, with its vivid yellow body and venemous sting, which ventures with impunity where it will; and the skunk which, if attacked, emits an evil-smelling fluid over its adversary which causes it to retreat precipitately. It is supposed that the outstanding colouring of such creatures is intended as a warning to their prey, and naturalists denote such brillancy as warning colour. On the other hand, we find insects, such as flies, with no means of offence, and with colouring that affords

no natural protection. In such cases, rapidity of breeding compensates for the destruction wrought by their foes.

Thus natural tinting, from brilliancy to the dullest brown or grey, helps to maintain the balance of lower animal life.

The process of extracting vegetable dyes and fixing them has been known and practised for thousands of years in the East, and the exquisite colours of Oriental carpets made by the Turks and Persians have lasted for centuries without fading. In Germany, the scientific study of dyes resulted in the formation of a great national industry, which rendered nearly every other country dependent upon the Germans for aniline dyes, the secret of which, before the war, was unknown in England, whose vast cotton and woollen industries so largely depended upon them.

The Sun has just set, the sky is clear, and from the deep blue overhead there is an exquisite range of colour to the western horizon. How are these effects produced ? By the Sun's rays encountering particles of dust and moisture in suspension at high altitudes. The light is split up into its component colour rays, which are reflected to the Earth at varying angles. Are we to suppose that these wonderful effects are accidental, and that there is no purpose in them ? Why do we call one another to see a beautiful sunset or a rainbow ? To gaze upon such beauties of Nature has a beneficial effect upon our physical well-being of which we may be quite unconscious. We are

impressed and sobered, and it makes us think "thoughts which we cannot express but only listen to"—as though they come to us from another world. If only for a few moments, it is good to have our minds sometimes lifted above the cares and monotony of life: and colour, like music, does this for us.

We walk forth in the spring, and tread the green grass sparkling with dew; wander beneath a delicate tracery of leaves and boughs meeting overhead, with glimpses of ethereal blue above; see the flowers springing up with warmth of colour and life; watch the birds in their bright plumage; gorgeous-hued butterflies; dragon-flies darting like streaks of blue and yellow light; glance upwards at white clouds drifting through the sky. Or, we may wander by a sea of blue and green, fringed with snow-white foam, or watch, at night, the Moon's "silver path" across the water. Whether it be in the spring or in the summer; in the autumn when the woods are clothed in their glory of russet green and gold, or in winter when they are mantled in purest white; we realize that, just as all other things in Nature serve some great and useful purpose, so colour fulfils an object in the Divine order of things.

CHAPTER XVI

THE ELEMENTS

BY an element is meant matter, or an ingredient of matter which cannot by any known means be resolved into two or more different ingredients. For instance, pure copper is an element, because whatever we do to it we cannot divide it into two things. Brass is not an element, because it consists of a mixture of copper and zinc which can be separated from each other. Hydrogen and oxygen are elements, and we cannot separate either of them into other gases.

Water is not an element, but consists of a chemical combination of oxygen and hydrogen, into which it can be resolved.

But although elements cannot be divided, most of them can be mixed, or chemically combined so as to form entirely different gases or substances. A few elements, which chemists hitherto have not been able to combine, occur in Nature only in small quantities. The best known of these are the two gases—helium and argon.

Most of the elements, however, combine with others, and in some cases their chemical affinity is so powerful

that they are never found in their elementary state, but only in combination.

A mixture is a very different thing from a chemical combination. For instance, if oxygen and hydrogen are simply mixed, nothing happens. But if a light be applied, they burn with great heat, or explode and form water, the same effect being produced by an electric spark passed through a jar containing a mixture in the proper proportions.

A chemical compound is a substance, resulting from a chemical combination. Chemical analysis is the separation of a chemical compound into its constituent elements.

If sufficient heat be applied to any known substance, it converts it into vapour or gas, and practically every known gas, if cooled sufficiently, can be converted into a liquid or solid. Although such changes are mechanically effected, chemical changes often result from the application of heat, or of heat and pressure combined. For instance, if we strike a match, as it burns away a chemical change takes place, so that the ingredients of the match cannot be restored to their original form.

Now, an atom cannot exist (except momentarily) by itself. Two or more always unite, forming what are known as molecules (little masses). One might almost express the idea by saying that amongst atoms there are no such things as bachelors or spinsters: it is all wedded life in a sphere where divorce is only permissible on condition of instant re-marriage.

It follows, then, that all matter, gaseous, liquid and solid, consists of molecules—particles so minute that if a single drop of water could be magnified to the size of the World, the molecules of which it consists would probably appear about the size of marbles. The density of matter depends upon the kind of molecules, the extent to which they attract or repel each other, and the speed with which they move; for however thin or dense a substance, the molecules of which it consists are in constant and rapid movement. A molecule is the smallest possible particle of a substance; that is to say, if one is divided, the atoms of which it consists separate and instantly enter into fresh combinations.

A molecule is quite a giant compared with an atom, which, in turn, as we have seen, is enormous compared with one of the electrons it comprises. When a chemical change takes place, these molecules behave in a curious manner: they first split up, not only into atoms, but sometimes into other molecules as well. Some conceive the strongest dislike for their neighbours, a battle royal ensues, and a new combination takes place, resulting in another substance or substances entirely different from the original.

If a piece of potassium or sodium (both light and soft metals) be dropped into water, a chemical change takes place, and the hydrogen of the water is liberated with such violence, and so much heat is generated, that the instant it comes into contact with the oxygen in the air it bursts into flame. This is quite a harmless

experiment. The fact that these metals have to be kept in naphtha, to prevent them from coming into contact with moisture in the air, is an interesting illustration of the powerful chemical affinity of certain of the elements for each other.

Common salt, which can be dissolved in water, and obtained again unchanged by evaporating the water, consists of a chemical combination of the metal sodium which, alone, takes fire in contact with water, and of chlorine, a yellow, poisonous and suffocating gas.

Another illustration, which will give some idea of the change that takes place when atoms combine, is that of sugar, which also can be dissolved in water. A piece of sweet, white sugar consists of tasteless carbon that will not thus dissolve, and of oxygen and hydrogen, both colourless and tasteless gases.

In some cases, light produces chemical action. Those who practise photography know that fact well. If chlorine and hydrogen be mixed in a dark room, nothing happens ; but if light be admitted, the gases combine and form hydrochloric acid. In other cases, invisible rays produce chemical changes which visible light does not effect.

Some materials, if perfectly dry, will not combine, whereas, if mixed in an ordinarily humid atmosphere they readily do so.

Great pressure will bring about chemical changes under certain conditions, and even sound will do this.

A slight shock will cause certain solutions of acids to turn instantly to crystals.

Another remarkable thing is, that sometimes two entirely different substances consist of the same number and the same kinds of atom as each other: this is perhaps one of the most puzzling things in physics, and leads one to imagine that perhaps after all the ambition of the old alchemists was not so foolish as is generally supposed. On the other hand, atoms of the same substance may comprise different numbers of electrons.

It is a strange reflection that these busy little molecules, atoms and electrons are always on the move, bumping into and circling round each other at enormous speeds, changing places, combining and driving each other about with never a pause, even in the most solid substances.

CHAPTER XVII

THE ATMOSPHERE

AIR is an elastic and almost transparent fluid, consisting of a mixture of two gases, oxygen and nitrogen, of which there are nearly 4 parts of nitrogen to 1 of oxygen (by volume). In addition to oxygen and nitrogen, it contains on an average about 1½ parts of water vapour, 1 part of argon, and minute proportions of dust, carbon dioxide (carbonic acid gas) and other things. Nevertheless, about 97½ parts out of every hundred consist of oxygen and nitrogen, and in whatever part of the World samples of air are taken, the proportion scarcely varies. That may seem strange, considering that animals are always using up the oxygen, but the explanation is that plants breathe as well as animals. When animals inhale, oxygen is retained by the lungs, entering microscopic capillaries, whence it passes into the blood, by which it is carried to every part of the body. There it combines with carbon, forming carbon dioxide, which is returned by the blood to the lungs and exhaled. The nitrogen serves to dilute the oxygen; for to breathe pure oxygen would destroy the lung tissues. Nitrogen also serves another purpose; it is essential to plant life.

Now, whereas animals inhale oxygen and exhale carbon dioxide, plants inhale nitrogen and carbon dioxide and exhale oxygen. That is Nature's method of maintaining the correct balance, although there are other factors, such as the discharge of carbon dioxide from volcanoes.

We are still faced, however, with the problem of how the two gases mix again so quickly and so uniformly all over the World, especially considering that nitrogen, being lighter than oxygen, might be expected to rise to a higher level. The reason is that they possess such an attraction for each other that the lighter gas is drawn downwards and the heavier one upwards, until they form a perfect mixture. This is proved by laboratory experiments. If a sealed jar containing hydrogen (which is nearly 14½ times lighter than air) be placed on a table, and another sealed jar, containing air, on the ground, and the two be connected by a tube, a quantity of the light hydrogen will make its way down into the lower jar and some of the heavier air will flow up into the hydrogen jar, so that in time both jars will be found to contain a uniform mixture of the gases. In the same way, the gases in the atmosphere mix and remain uniform in quantity. This is known as " diffusion " of gases. Incidentally, the process is doubtless accelerated by air currents.

The greater the altitude, the rarer and colder the air becomes until, at a height of about 8 or 10 miles, a temperature of —65 degrees centigrade is reached. The

coldness of interstellar space was at one time thought to be more intense than that at which all gases would be liquified (or even frozen solid), but that is not borne out by another theory that the oxygen and nitrogen mixture is overtopped by an envelope of helium which stretches as far as the moon. Certainly falling meteorites indicate some sort of atmosphere at a height of 100 miles or more, whilst phenomena, such as the Aurora Borealis, appear to demand a layer of helium extending to a height of more than 1,000 miles, to explain their manifestation.

Since oxygen liquifies, at atmospheric pressure, at −182.5 and nitrogen at −195.5 degrees centigrade ; if the cold of space were absolute (i.e. −273 degrees centigrade) it might be supposed that, at certain heights, oxygen and nitrogen would be liquified, and furthermore, that the whole atmospheric blanket would be encased in a more or less spherical shell of frozen helium !—but here we are faced by the problem as to whether the ordinary laws of physics hold good at great altitudes. Experiments with balloons, extending over many years, appear to indicate that, above a certain height, temperature does not decrease uniformly as was once supposed : for instance that, at elevations of from 8 to 15½ miles, the temperature does not greatly vary, averaging, about, −65 degrees centigrade. Unfortunately, however, these experiments do not determine whether temperature falls to lower levels at still greater altitudes.

The question of gravity has also to be taken into consideration. As the temperature of a gas decreases, its density (and therefore its weight) increases, with the result that at a certain temperature a gas must reach a density at which its weight counteracts its relative buoyancy. Consequently, if at greater altitudes than those mentioned, temperature falls sufficiently, we can only think of air (as we know it) as reaching a point above which its molecules can rise no further. If this argument holds good, it follows that both oxygen and nitrogen (as well as other gases in the atmosphere) must end at altitudes above which only lighter gases with lower liquifying points can exist. We are led then to the supposition that the outermost layer of our atmospheric blanket may consist of helium—the second lightest gas known.

An interesting reflection is that, just as the Moon causes the ocean tidal wave, so it may set up an immense atmospheric tidal wave.

Whilst the Earth rotates at a speed of 1,000 miles an hour and travels at 66,000 miles an hour in its orbit, its envelope of air revolves and travels with it, clinging tenaciously to the surface. For air possesses weight, and a cubic yard weighed in a vacuum at sea-level weighs just over two pounds, while the weight of the whole volume of air exerts a pressure on everything, and in every direction, of nearly 15 pounds to the square inch. Thus, the total pressure on a full-grown man amounts to about 14 tons.

THE ATMOSPHERE

The atmosphere serves to protect the Earth from the full effect of the Sun's rays, which, in passing through it, lose about half their power, so that they only strike the Earth with about one half of their original force.

It has been calculated that, if the heat absorbed by the atmosphere from the Gulf Stream alone, could be utilised, it would generate sufficient power to drive engines of three billion horse-power.

In the tropics the atmosphere is at freezing-point at a height of about 3 miles. In latitude 45 degrees, freezing-point is reached at an altitude of about 1½ miles, more or less, according to whether it is summer or winter time, and to other local conditions. In the Arctic and Antarctic regions it is at sea-level.

Air is the medium that circulates water all over the World. It evaporates moisture from vegetation, from the sea, and from all other water, that rises as invisible vapour, and is carried by winds until, upon meeting colder currents of air, the vapour condenses and falls as rain, cleansing the air and refreshing the Earth and sea. Falling also as snow, on mountains and in polar regions, it gives rise to glaciers and icebergs, which in turn serve other great purposes of Nature.

Wind is the result of a simple, natural law. When air is heated, it expands, so that for a given volume it is lighter than when cold. If warmed, it rises, and cooler air flows into its place. Consequently, when the surface of the Earth is heated by the Sun, air

in contact with it is heated and rises : in the tropics great volumes are heated and rise so rapidly that the atmosphere is affected for thousands of miles, causing strong, steady winds to blow in certain quarters for nearly 6 months at a stretch. At the times of the spring and autumnal equinoxes, when winter conditions are changing to those of summer, and vice versa, these winds gradually veer round in other directions and we experience what are called equinoctial gales until they blow steadily again. These long-sustained winds were named trade winds, because sailing ships were able to rely upon their regular assistance. The direction of the trade winds south of the equator is generally north-west, while those north of the equator blow towards the south-west. If it were merely a question of cold air flowing from the poles to the equator, these winds would flow in northerly and southerly directions respectively, but although the atmosphere revolves with the Earth, apparently it lags behind to some extent, and thus causes a compromise between north and west, and between south and west in their course.

The subject, however, is a complicated one, since winds are deflected from what might be termed their natural course by many influences, such as the varying temperatures of localities over which they pass. Consequently, wind charts do not always indicate directions that might be expected.

Land and sea breezes are the result of heat escaping more rapidly from the sea and land respectively :

thus, in the daytime, cool air from the sea blows towards the land, taking the place of air which has been rapidly warmed and has ascended. At night-time, the land having become colder first, air flows from it seawards to take the place of comparatively warm air rising from the sea.

Variable winds and storms are caused by complications affecting currents of air. The currents are diverted according to whether they pass over sea or land; in places where clouds collect, the Sun's rays are partially obstructed, and rain or snow falling through the air alters its temperature at various levels. Consequently, the courses of all, except trade winds, are constantly upset, and a wind blowing in one direction is often overtopped by others blowing in opposite directions.

Prevailing winds are those which, although not necessarily regular, for the most part blow uniformly. Thus, a prevailing south-west wind is one which, in a given country and for a given period, blows mainly from the south-west.

Various names are given to different winds according to their character and the countries in which they occur. There is the poet's zephyr, a soft cool breeze that tempers the heat of the Sun; the boisterous gale that braces and invigorates youth; cold north and east winds, that so often herald death; trade winds, on which the prosperity of nations was built up in the old days of sailing ships; the tornado, or whirlwind, that circles violently round and round as it

travels, to the accompaniment of thunder and lightning; the simoon, a terrible hot air and sand-storm that stifles and blinds travellers in the desert and turns day into night until it has passed; and the hurricane travelling at 100 miles an hour, wrecking ships, uprooting trees, razing buildings to the ground, and spreading desolation in its track.

Wind disperses the seeds of plants, and carries pollen from flower to flower. It sweeps foul air from unhealthy places, and smoke and poisonous fumes from cities and manufacturing districts. And it creates waves at sea, about which more will be found in another chapter.

Great quantities of dust are caught up from sandy deserts and carried immense distances by winds. In the year 1898, a ship named the "Roslin Castle" ran into a haze of dust so dense that, for a stretch of 900 miles, it obscured the heavenly bodies and endangered the safety of the vessel.

If a closed tank were exhausted of air, so as to create a vacuum, air, when again admitted, would rush in to fill the tank at a speed of 800 miles an hour. Its extreme temperature under natural conditions ranges from about 153 degrees Fahrenheit to 81 degrees below zero—a difference of 234 degrees—but in any given locality its temperature seldom varies by more than 170 degrees at sea-level. At greater altitudes the temperature falls 1 degree for about every 250 feet of rise. Under the influence of heat it expands, and with an increase of about 500 degrees,

occupies twice the space ; if prevented from expanding, its pressure would be doubled, i.e. would be increased to nearly 30 pounds to the square inch. Under a pressure of $5\frac{1}{2}$ tons per square inch, it becomes as dense as water, but upon release expands again to its original volume. By subjecting it to pressure and rapidly cooling it, air may be reduced to a liquid condition, and if subjected to a temperature of —200 degrees centigrade it liquifies without the application of pressure. At a temperature of —253 degrees centigrade, all gases other than helium are frozen solid.

In addition to its natural use, there are its artificial uses to consider. Air is a bad conductor of heat : consequently, in the hollow walls of buildings it serves to retain warmth within. Under compression, it may be used to operate pneumatic machines and tools, or may be forced through pipes to drive out water from foundation works, enabling operations to be carried on at 100 feet below water-level.

The extraction of nitrogen from the air is now an important industry : hundreds of thousands of tons are extracted yearly for the production of nitrates used as artificial manures and for the manufacture of explosives.

Colourless, odourless, restless, almost intangible, air is the first and last essential to life. The first breath inhaled by an infant produces a wonderful effect : at birth its tiny lungs are yellow in colour and

lie folded close together, but as the air reaches them they flush to a rose-red hue and expand like the petals of an opening flower. Thereafter, with no conscious effort, the child continues to breathe, and that is his last as well as his first act in life.

CHAPTER XVIII

THE WONDERS OF WATER

PURE water is a chemical combination of oxygen and hydrogen in the proportion of one volume of oxygen to two of hydrogen, the proof being that water may be divided into these two gases again. By way of experiment, pour some water into a glass jar and add a little sulphuric acid. Then, take two metal plates—preferably platinum foil—with a copper wire attached to each, immerse them in the solution and connect the wires to a fairly powerful battery. The electric current from the battery passing from one plate, through the water, to the other, will gradually change the water into its two constituent gases again. Tiny bubbles of oxygen will collect on one plate and hydrogen bubbles on the other. This analysis of water is known as electrolysis.

Hydrogen is the lightest gas known, and is 14½ times lighter than air. Oxygen is slightly heavier than air. Now, although these two gases can be compressed into a much smaller space by pressure, water, which consists of them, is one of the most imcompressible things known. It is only by applying heat or very great pressure to it, or by freezing it, that its volume can be appreciably altered. Confined in a steel casing,

it will resist tremendous pressures. A hydraulic jack is a steel cylinder, with a piston or ram fitting into it so that no water can escape. In the bottom a valve is fixed through which water is pumped into the cylinder. The jack is placed under a load to be lifted, and, as water is pumped in, it lifts the load. Hundreds of tons can be raised in this way by a single jack, the weight of the load being borne by the water inside the case. By means of machines, called hydraulic accumulators and intensifiers, water can be subjected to a pressure of more than 5 tons per square inch without appreciably reducing its volume: yet, if the vessel containing it were to crack, there would be no explosion such as steam or compressed air would cause, because the instant it cracked, the pressure would be reduced to nothing. Laboratory experiments with pressures of hundreds of tons to the square inch have proved that water, once regarded as incompressible, can be reduced in volume by one-third of its bulk.

Under atmospheric pressure water is densest when its temperature is 39 degrees Fahrenheit. If it becomes hotter or colder than this, it begins to expand and to occupy more space: for instance, when it freezes. That is why water pipes burst in frosty weather: the water they contain expands as it turns to ice, and splits the pipe, but this only becomes manifest when the thaw sets in and the ice melts. In the act of changing to ice, it exerts a pressure of 14 tons to the square inch.

Water, like air, is never found quite pure in Nature, but contains various salts and minerals in solution. The most nearly pure water in Nature is rain-water.

A cubic foot of fresh water at 32 degrees Fahrenheit weighs 62½ pounds, and a cubic foot of ice at 32 degrees weighs 57¼ pounds: that is why ice floats in water.

Sea water of average density weighs 64 pounds, and freezes at or below 27 degrees: when it freezes, the salt separates from it so that the ice is quite fresh. Salt water being heavier, some things will float in it which would sink in fresh water: hence it is easier to swim in sea water.

Fresh water boils at 212 degrees at ordinary atmospheric pressure. It changes to steam also at this temperature, if enough heat be applied to it.

When a kettle boils—to use a homely if incorrect phrase—the white jet issuing from the spout is not steam, but visible vapour caused by its condensation, for steam is an invisible gas. If the kettle boil vigorously enough, however, a space will be noticed between the spout and the white jet, this space being occupied by the steam just before condensing. When sufficiently heated steam becomes perfectly dry, and so hot that it scorches like a fire, yet if cooled it changes to water again, because the atoms have not separated. If, however, a sufficient amount of heat were applied, the oxygen and hydrogen atoms would separate and, anomalous as it may appear, would require to be

mixed and fired with a flame before they would combine and form water again.

We may have water in one jar and ice in another, both at 32 degrees Fahrenheit, and if the temperature of the surrounding atmosphere remain at exactly 32 degrees, the water will not freeze and the ice will not melt, the reason being that it requires the extraction of many heat units to change water to ice at the same temperature, and, conversely, the application of many heat units to melt ice. If the temperature of the air be ever so slightly above 32 degrees, the ice will absorb heat from it and gradually melt, although, when melted its temperature will still be only 32 degrees. On the other hand, if the atmospheric temperature be ever so little below 32 degrees, the air will absorb heat from the water, which will freeze, although its temperature will still remain at 32 degrees.

Again, we may have boiling water and steam both at 212 degrees, although to change one to the other necessitates the application or withdrawal of a great many heat units.

If we add 1 pound of water at freezing point (32 degrees Fahr.) to 1 pound of water at 212 degrees, we get a mixture of 2 pounds of water at 122 degrees Fahrenheit. On the other hand, if we take 1 pound of steam at 212 degrees, we find that no less than $5\frac{1}{3}$ pounds of water at freezing-point can be added to it so that we have a mixture of $6\frac{1}{3}$ pounds of water still at 212 degrees, thus proving the greater quantity

of heat contained in steam at 212 degrees than in water at 212 degrees ; this extra quantity of heat is called the " latent " heat of steam.

Water in contact with air that is not too moist evaporates, although the air may be quite cold. When it evaporates under natural conditions it leaves solid impurities behind, no matter whether it was in a stagnant pond or mixed with foul or poisonous matter.

Clouds are portions of the air charged with minute particles of moisture, cold enough to be visible, but not cold enough to condense into raindrops. The darker the clouds, the more nearly ready they are to form rain.

After a hot summer day the Earth loses its surface heat rapidly and becomes cooler than the air, causing vapour in the atmosphere to condense into tiny beads of moisture on everything that does not absorb them. These globules run together and form dewdrops. In certain hilly districts hollow spaces are scooped out in which dew or mist collects, forming ponds of water. They are variously called dew or mist ponds, and provide drinking water for sheep and cattle. Hoar frost is dew, frozen before it can form large drops.

Mists and white fog are caused by encounters between warm and cold currents of air or of water, or by vapour partially condensing near the Earth's surface.

The air in contact with water and vegetation

A Boiling Spring in the middle of a Cold Water Lake in Yellowstone Park, U.S.A.

In a tiny island surrounded by cold water, is a boiling spring, and at one time fishermen used to stand on the island, catch trout, drop them straight into the boiling water, and cook them on the spot. A practice now stopped.

By courtesy of the National Park Service.

evaporates enormous quantities of moisture, carrying it in suspension. In some places, water is drawn bodily upwards by the wind whirling rapidly in a circle and forming a great funnel, up which the water is sucked into the atmosphere, where it evaporates. Such occurrences are known as waterspouts. They are often four or five hundred feet in diameter, and occasionally wreck ships. Fish are caught up by them and afterwards fall in showers, sometimes on the decks of steamers.

Rain, of course, consists of drops of water condensed from vapour upon encountering currents of cold air. When it falls through a very cold stream of air, the drops freeze into hailstones which, in certain parts of the World, are 6 inches in diameter.

Vapour also crystallizes into minute particles that freeze together, and we get snow : on high mountains above the snow-line it never rains, because there vapour can only crystallize into snowflakes. Sometimes, when falling, snow passes through a warmer stratum of air that partly melts it into sleet.

Of the many wonders of Nature, so familiar that they pass almost unnoticed, water is one. Constituting the bulk of every living thing, its almost endless applications are such that without it all life would cease. In its manifold changes it is indestructible, disappearing only to appear again in another form in the constant service of Nature and civilization. Drink it, and thirst is quenched, and almost immediately it is coursing through the system, through the

heart and blood vessels, purging the body of poison, which it carries off in solution.

Befoul it, and a process of purification immediately commences by filtration through the soil, whence it emerges as a crystal stream ; or by evaporation in the atmosphere whence it falls as rain, cleansing the air, refreshing the Earth and, absorbed by vegetation, commencing another cycle of usefulness. A solvent of most known substances, it is indispensable in chemistry and medicine. Imprisoned by the engineer, its great resistance to compression enables it to transmit enormous power ; heat it, and it changes to an invisible gas, the usefulness of which lies in its high degree of elasticity ; cool it, and it regains its original form ; freeze it, and it becomes a solid block of brittle crystals. Restless, never stationary though it seem to be, used and cast aside, contaminated by man and beast, it is ever self-purifying and a purifier. Ubiquitous in the performance of innumerable duties, it is a wonderful agent and faithful servant, but a pitiless master, fatal to life and destructive of the works of Man. By the tireless energy of river and sea, through untold ages, it has continually changed and is still changing the face of the Earth, levelling mountain with plain and wearing rock to dust. Ascending into the atmosphere as vapour, or a waterspout in one place, it descends in another, forming mighty rivers by which navigation is carried far inland. Frozen into immense fields and mountains of ice in the polar regions, and ever breaking away, it

drifts as icebergs into warmer seas, melting as it travels.

By its action is created the beauty of sea and landscape as seen in the rugged coast, the waterfall, river and lake. Withheld, vegetation withers and we find but desert waste, affording sustenance of no kind. Now, it is the carrier of poison, disease and death : a moment, and it is an emblem of purity—the vehicle of life.

CHAPTER XIX

THE SEA

WHY is the sea salt ?

That is one of the first, and one of the most natural questions asked in connection with the sea. From time immemorial water has constituted one of Nature's principal forces in the disintegration of rocks, and being the greatest of all solvents, readily absorbs and holds in solution various salts and acids with which it comes into contact. The reply, then, is that the salinity of the sea is due to the quantity of salts dissolved from minerals and held in solution. On an average, in 100 parts of sea water there are $3\frac{1}{2}$ parts of various salts, most of which is common salt that we take with our food. But its salinity varies considerably : in the tropics, where evaporation is rapid, since salt does not evaporate, the proportion is 4 instead of $3\frac{1}{2}$ parts in 100. (The salt we sometimes detect in sea air is due to the wind catching up spray and holding it in suspension.) On the other hand, where evaporation is less rapid, or where great rivers, like the Amazon, discharge enormous quantities of fresh water, the proportion is sometimes less than 1 in 100.

If the sea were always still, its salinity would probably increase in places until it contained nearly 2 parts of salt to every 5 of water, while in other places the amount would be imperceptible. But that is prevented by those ceaseless movements of water brought about by the action of the Sun's heat; by ocean currents, winds and waves, evaporation and rainfall.

Notwithstanding its resistance to compression, it has been calculated that water is compressed at ocean depths to such an extent that the average level of the sea is 116 feet lower than it would be if water were absolutely incompressible. The temperature of the sea is not directly affected by the Sun to a depth of more than about 300 feet; below that the water is ice cold, even in the tropics where the surface temperature reaches 94 degrees Fahrenheit. Below a depth of about 500 feet, it is undisturbed by waves.

Ocean currents are due to a variety of causes. In the tropics the Sun's heat causes the surface water to expand and push away the adjacent water. This sets up warm flows towards the poles, which in turn cause counter currents of ice cold water from the poles towards the equator, bringing icebergs with them. Again, prolonged winds like the trade winds do not glide without friction over the sea, but drag the surface water after them and thus set up surface drift currents. Another contributory cause is the discharge of volumes of water from great rivers affecting the sea for distances of hundreds of miles. The tides also set up

currents, especially when passing through restricted passages such as the Straits of Dover : and there are still other contributory causes too complex to enter into here.

Now, all these currents are subject to varying local conditions, and are affected by the configuration of coast-lines. Nevertheless, although they are a compromise between the effects of various causes and obstructions, certain definite ocean currents such as the Gulf Stream result, and their effect is to keep the sea in continual motion, to assist in maintaining a fairly constant average degree of saltness by thoroughly mixing the waters, and to prevent stagnation, even beneath a tropical sun.

The regularity of certain currents is of great assistance in navigation. Again, by charting them, it is known when and where icebergs may be expected, so that collisions, such as that by which the " Titanic " was sunk, may be avoided.

Strangely enough, one of the nearest approaches to stagnation occurs in patches in mid-ocean. When ocean currents encounter land, they are diverted and sweep along the coast, finally turning seaward again, describing curves enclosing more or less undisturbed water in which dense masses of seaweed collect which, by their oxygenizing effect, prevent it from becoming foul. It is said that vessels have been stopped and entrapped by such weed in the Sargasso Sea.

In this way, much impure matter is carried away and dispersed : a process that the rise and fall of the

tide would not effect. Indeed, tides and waves are apt to cast up sewage and other impurities on to the shore, leaving it for the sun, wind and rain to effect final dispersal. Thus, it is largely to ocean currents that we owe a healthy condition of our coasts.

Sea waves, tides and currents wear away the coast in some places and build it up in others. Waves wash away materials at the base of cliffs, and, when a certain amount has been removed, a mass tilts forward and falls. But what the sea wears away in one spot, it deposits in another. First, waves break up the fallen mass and wash it out flat. Then (for it will have been noticed that on a straight stretch of coast the waves nearly always approach at an angle), they work it along the shore and pile it up somewhere else. This is known as littoral drift, to prevent which groynes are constructed on the sea-shore. Even in the short spaces between groynes, the sea scours away the shingle from the side of one groyne and piles it up against the next. But for such protection, storms would sweep away large stretches of beach, undermine and destroy the sea-walls of esplanades and seriously encroach upon the land.

Sea water holds, in solution, many things besides common salt. Gold is one: it has been estimated that the quantity of gold distributed throughout the ocean is millions of times greater than that extracted from the Earth—unfortunately, however, the process of securing it would cost more than the value of the gold recovered.

It is no uncommon thing, when fishing at night, to see one's line covered with a phosphorescent glow which appears on everything wetted by the water; while darting fish make flashing streaks of light. This phosphorescent glow is caused by myriads of animalculæ. So abundant are they at times on the water that the names of ships can be read by their light.

The fauna and flora of the sea are legion in number and variety: it is said that if meat were unobtainable, there would be a sufficient harvest of fish to feed the entire population of the World.

In the Arctic regions, the waters are frozen into fields of ice, varying from a few to many hundreds of feet thick. The limit of the ice fields varies with summer and winter conditions: from the frigid zone, they extend farther south in the winter, so that ships trading between certain ports have to run the gauntlet of masses of floating ice. Specially constructed vessels called ice-breakers are employed to keep a passage open. These vessels charge the ice; their bows rise over the edge, and, crashing through it, break it to pieces. The operation is repeated until a passage has been cleared, enabling ordinary vessels to pass.

Every ocean, every sea has its own particular interest, just as every country has its story. Space only permits of one brief illustration, and we will take the Pacific Ocean, which surely was misnamed, for hardly any region of the World is more disturbed. Extending from the Arctic regions, across the equator,

and terminating in the Antarctic, this ocean and the shores bordering it embrace every gradation of climate and produce almost every species of fauna and flora. It is ringed round by vast mountain chains extending from Tierra del Fuego in the south, right up the western shores of the Americas to Alaska in the north, and thence south again via Japan to Australia, New Zealand and Mount Erebus. These mountains are perforated by mighty volcanoes, so that the Pacific may be said to be encircled by fiery peaks. Shaken continuously by earthquakes, its bed for ever rising and falling, this great ocean probably constitutes a safeguard against still more fearful catastrophes in other parts of the World. In its bed are many depressions, some nearly six miles deep.

Amongst other marvels of the sea mention must be made of atolls—interesting and wonderful formations. Around the base of an island, in the depths of the ocean, myriads of corals laid the foundation of a mighty ring, and upon this base patiently but persistently built up an encircling reef, which at last reached the surface, forming a lagoon round the island. Waves breaking upon the reef broke off masses of coral, hurling them on top of the reef, thus raising its level. Seaweed formed a first garment of vegetation, and seeds of various plants, drifting with currents or carried by winds and birds for hundreds or perhaps thousands of miles, lodged upon this first layer of vegetation and took root ; so that, in time, the atoll became clothed with tropical growth, and a beauty

spot was set in mid-ocean. The presence of an island is not, however, essential to the growth of these islands, which are also found where no island exists.

If we stand on the seashore on a rough day and watch the waves breaking, we witness but their end —the final expenditure of energy imparted to and transmitted by them through long distances, sometimes as much as a hundred miles. The first breath of an approaching storm roughs the surface of a tranquil sea into ripples, themselves tiny waves, and every succeeding impulse of wind imparts fresh energy. As the waves rise in height, they present a greater surface to the wind, which is thus enabled to exert more and more force upon them; and as it sweeps onwards, its cumulative effect produces ever-increasing undulations of the water in its track, so that even after a wind-storm has passed the coast-line, the waves, travelling more slowly, continue to approach in force. When the wind changes direction, or drops before reaching the coast, the waves, continuing their course, partially expend themselves against undisturbed water and approach the shore in smooth undulations known as ground swell.

As waves near the shore, one is apt to suppose that the water itself is travelling, but this is only true in most cases to an almost imperceptible extent. The actual travel of the surf after a wave has broken only represents the visible effect of expenditure of wave energy. If an up and down motion be imparted to a long rope at one end, it assumes an undulating

form, each impulse passing through the rope to the other end ; so it is with most waves which are known as waves of oscillation ; the water is merely a medium for the transmission of energy imparted to it, just as the rope is the medium for transmitting force communicated to it at one end. But there is another

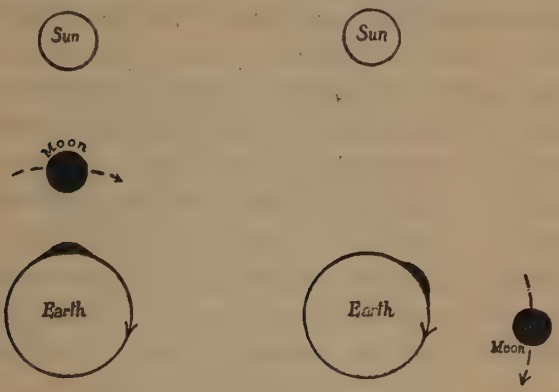


Fig. 5.—Sun, Moon and Tides

When the Sun and Moon are on the same side of the World and the three are more or less in line, the tides rise higher and fall lower than at other times. When the three are in the position shown on the right the attraction of the Sun partly neutralizes the pull of the Moon and the tidal wave then rises and falls to a less extent. In each figure the wave is shown in a purely arbitrary position as it does not keep pace with the Moon in its apparent journey round the World as the Earth rotates.

type of wave less frequently encountered, known as a wave of translation, in which the water itself moves bodily forward, due to prolonged wind action, tides and currents.

Off Cape Horn and the Cape of Good Hope waves are encountered measuring 1,000 feet from crest to

crest, 60 feet high, and attaining a speed of 30 miles an hour.

The tidal wave is due to the attraction of the Moon and Sun, and the rise and fall of the tides to the wave being obstructed by land. The Moon draws the sea up to a slight peak on the side of the World facing it, and this peak of water travels across the oceans, where it attains a height of about 2 feet and a speed of 400 to 500 miles an hour. As it approaches land, its course is obstructed and its direction changed: thus, as it nears Great Britain, it is diverted up the west coast of Ireland into the Irish Sea and along the English Channel, and, moving forward in these restricted spaces, rises in height to as much as 35 feet at St. Malo on the French coast. In the Bay of Fundy it attains an altitude of 70 feet. When the Sun and Moon are both on the same side of the Earth, or on opposite sides, their pull is greatest and we get spring tides. When they are at right angles in relation to the Earth, the resultant of their pull is less and neap tides occur. At high spring tides, when the wave passes up a still more restricted passage such as the mouth of a river, it rises higher and higher as the channel becomes narrower, sometimes reaching a height of 15 feet, as in the case of the Amazon. This form of the tidal wave is known as a bore, and unless precautions are taken beforehand, it is liable to cause great damage to shipping and riverside works.

The tremendous force exerted by waves has been

variously estimated, and actual experiments have indicated pressures as high as 3½ tons per square foot of surface exposed to them. The following are examples of the extraordinary and destructive effect of wave action during heavy storms. A lighthouse fog bell off the Scilly Islands, at a height of 100 feet above high water, was torn from its brackets ; in 1881 the iron tower of the Calf Rock Lighthouse was broken off at 86 feet above high water. In 1869, 14 stones weighing 2 tons each were torn out of the Dhu Heartach Lighthouse 35 feet above high water. At Alderney, blocks of stone of 9 tons each have been lifted by the sea and hurled over the breakwater, a height of 45 feet. In 1896 and 1897, masonry blocks weighing 40 tons each, embedded at a depth of 23 feet below low water in the Peterhead breakwater, were displaced and washed away ; and in the following year a solid mass of masonry, weighing 3,300 tons and constituting a portion of the breakwater, was slewed bodily 2 inches out of position by the waves which on that occasion rose 30 feet high and which, upon breaking, threw up water to a height of 120 feet. In moving this enormous mass, the waves exerted a force of 2 tons per square foot, or a total force of 2,300 tons upon the displaced section. At Ymuiden, in Holland, a 20-ton block was thrown up by the waves to a height of 12 feet and landed on top of the breakwater. In 1872, a mass of masonry in the Wick breakwater, weighing 1,350 tons, was torn out of position and deposited alongside ; and in 1877,

another mass, weighing 2,600 tons, was carried away bodily and broken in two.

Such instances of the destruction wrought by waves may induce wonder as to what useful purpose they serve. Suppose that, throughout a hot summer, the sea in a bay or off a stretch of coast were always still, the water would become hot and foul and a breeding-place for fever and disease germs. Even far out at sea, the water is warmed down to a certain depth and similar conditions would obtain. Waves are another of Nature's methods for preventing stagnation, and maintaining that freshness essential to health and life within and around the seas and oceans of the World.

How many who stand on the seashore realize that they are in one of the most wonderful spots on Earth—where land and sea meet ?

Æons ago, the first lowly forms of life appeared where the warm seas lapped the shores. All those old coast-lines disappeared, land and sea changed places, mountains were upheaved, and new coast-lines formed. Even now, although a lifetime in most cases is insufficient to detect any difference, coast-lines are continually changing their contour, either as the result of elevations and depressions of the Earth's crust, sudden falls of cliffs, or the gradual and almost imperceptible erosion of the coast. Every wave, great and small, performs its share of the work, whether it be to fling about and smash great masses of rock, or to roll and wear away the shingle to

grains of sand. Here, on a rocky coast, where Nature has raised ramparts of solid granite, the sea attacks in its greatest strength. There, on a sandy stretch, it recedes and compensates for the toll it has taken elsewhere. Where we stand now may in ages to come be 1,000 miles from the sea and raised to snow-clad heights, or lowered to ocean depths.

CHAPTER XX

WATERSHEDS, RIVERS AND LAKES

A WATERSHED is a natural ridge or group of ridges, varying from small hills to mountain ranges, that determine the directions in which streams flow. River basins are areas of ground from which most rivers derive their water supply, not merely at their source, but for long distances.

Rain falling in a river basin percolates the ground or runs down the sloping sides of rocky ground and, following lines of least resistance, wears away grooves or channels. When water that sinks into the ground encounters impervious strata, it issues again in the form of springs that well out in valleys or from the sides of hills. Many streams are so formed which, flowing downward, join forces, eventually constituting a river.

Each stream performs its share of denudation and carries its quota of sediment into the main river. The heavier and larger particles are deposited in the beds and washed down by degrees, generally when the streams are in flood. But in addition to these heavier materials the water holds in suspension finer, solid particles, which often cause discoloration. In this way enormous quantities of mud are carried down to

the sea. It has been estimated that the Ganges alone, during four months of the wet season, every year discharges between three and four hundred million tons of mud.

In their course through low-lying country many rivers overflow their banks periodically, depositing over the adjacent land millions of tons of rich mud, thereby enriching the soil.

Some rivers, notably those which discharge into seas where there is only a small rise and fall of the tide, in the course of time deposit so much sand and mud at their mouths that great areas become blocked up, and the estuary divides into a number of different streams that wear many channels through the beds so formed. These areas are called Deltas, from the Greek letter "delta," denoted by a triangle thus Δ, as it is more or less this shape that the beds take. The delta of the Mississippi is twice the size of Yorkshire. In other cases, sea currents outside the river estuaries deposit quantities of sand, forming what are known as bars and sandbanks.

In their lower reaches, when traversing flat country, rivers carve out very winding courses. When in flood, the centrifugal force of the current scours away the banks on the outer sides of the curves, adding to the charge of materials carried down to the sea. The stream tends to become more and more tortuous and gradually shifts its bed. Sometimes the bends become so exaggerated that the land between two of them is eroded and the current takes a short cut

across what was once a neck of land. Occasionally rivers divide into two in the direction of their flow, sending a portion of the water in one direction and the remainder in another: this is called bifurcation. Many great rivers originate where the lower ends of glaciers melt, and thus owe their origin to snow high up in the mountains.

The Colorado Canyon is a striking instance of the erosive power of running water. The Colorado River existed before the mountains through which it flows were raised, and the river coursed through almost level plains. Then the upheaval began. Slow as it was, it gave the river its full task to wear a way through the successive strata that rose in its path. Six thousand feet high rose the rock, and through it the river scoured gorges, in some places 6,000 feet deep, for 300 miles, using masses of the rock itself as excavating tools. That titanic struggle is unfinished yet.

In some cases rivers flow underground through natural tunnels for miles at a stretch. Another kind of subterranean flow occurs in districts where there is much limestone. Water possesses the power of dissolving one of the ingredients of limestone and rendering it porous, and, having thus prepared a path, so to speak, sinks into and flows through the rock instead of along the surface.

In certain localities wide and deep depressions or "basins" have been formed by movements of the Earth's crust, in which layers of chalk and other

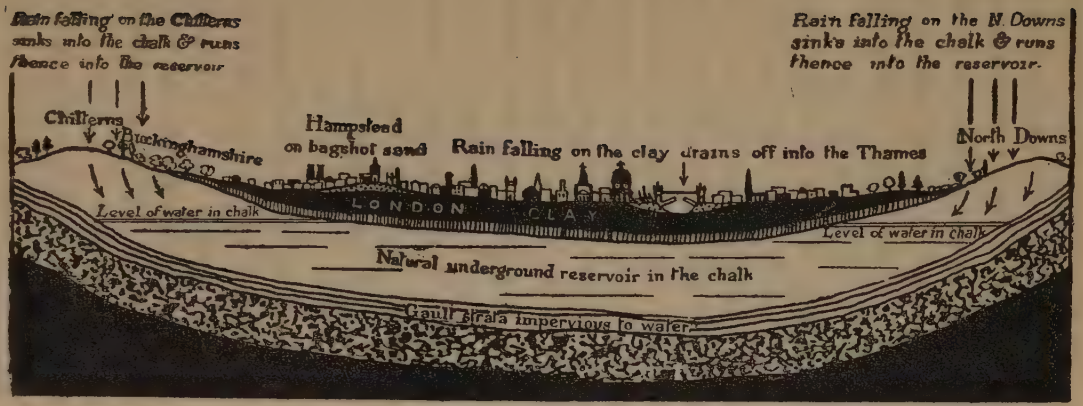

Rain falling on the Chilterns sinks into the chalk & runs thence into the reservoir
Rain falling on the N. Downs sinks into the chalk & runs thence into the reservoir.
Chilterns
Buckinghamshire
Hampstead
on bagshot sand
Rain falling on the clay drains off into the Thames
North Downs
LONDON
CLAY
Level of water in chalk
Level of water in chalk
Natural underground reservoir in the chalk
Gault strata impervious to water

Fig. 6.—THE RESERVOIR UNDER LONDON

A great stratum of chalk, underlying the London clay, serves as an immense reservoir for water which is prevented from escaping by underlying strata of gault. The water enters the outcropping chalk great distances away, percolating downwards until the chalk reservoir is almost full.

rocks lie upon a stratum impervious to water: rain percolating porous strata near the edges of such a depression makes its way towards the centre, until the layers are saturated, so that, if a hole be bored through the overlying strata, a magnificent supply of almost pure water can be obtained. London, Paris and Vienna are situated over such basins.

Moisture absorbs carbon dioxide from the air, and this enables water, when percolating limestone, to take up calcium carbonate. When drops of water so charged force their way through the superincumbent rock, through the roof of a cave, before falling, they deposit minute particles of the calcium carbonate, and, after falling, deposit more of their charge on the floor of the cave. These deposits accumulate and, in course of time, form icicle-like pendants and pinnacles, most beautiful in colour and effect. Those that hang from the roof are stalactites: those that project upwards from the floor, stalagmites. In time, they meet and form tree-like columns.

Waterfalls and lakes are interludes in the courses of rivers. A magnificent example of waterfalls is that of Niagara, of which the water, where it pours over the edge of the precipice, is 20 feet deep. The falls are half a mile wide and have a sheer drop of 160 feet. Another instance is that of the Victoria Falls on the Zambesi, with a total height of over 350 feet.

Salt water lakes were formed by water, charged with salts collected from surrounding areas, draining into

natural depressions or basins, which had no outlets. Evaporation of the water left the salt of which more and more accumulated as the streams continued to flow into the lakes. Thus, as time passed, the water became salter and salter. The Caspian Sea is the biggest salt water lake in the World. The Great Salt Lake in the Rocky Mountains and the Dead Sea are instances of lakes so salt that no life can exist in them. The Dead Sea is an especially interesting instance: the River Jordan, originating from melted snow, passes through the Sea of Galilee (a freshwater lake), and drains into the Dead Sea, which, 1,300 feet below sea-level, has no outlet. In British East Africa there is a basin or depression called the Magadi Lake, filled with soda crystals, brought down and deposited by streams.

Other lakes formed in the craters of extinct volcanoes, and in ancient glacier beds, the lower ends of which became choked up and dammed by rocks and mud, originally brought down by the glaciers.

The largest freshwater lake in the World is Lake Superior, covering an area equal to that of Ireland and having a depth of 600 feet in parts. It is fed by 200 rivers.

Mountain lakes are generally long, narrow and deep, with steep sides, of which the lochs in the Highlands of Scotland are examples. Those in low-lying country are usually shallow and broad, with low shores: they often occur in the courses of rivers and are sometimes merely enlargements of the river beds.

WATERSHEDS, RIVERS AND LAKES

Valleys are depressions, in some cases resulting from elevations of the Earth's crust ; in others, they have been gradually carved out by rivers or glaciers. Frequently valleys between bleak hills are fertile ; materials worn from the rocks having been deposited in the depressions, thus providing a depth of soil enriched by decayed vegetable matter, and watered by springs, streams and surface water from the hills.

Valleys in mountain ranges generally extend upwards, enabling roads and railways to be constructed from both ends, sometimes to within a few miles of each other, so that it is only necessary to tunnel for short distances through the summits of the mountains. Tracks made between or round mountain peaks, to connect roads on either side, are known as mountain passes.

CHAPTER XXI

CLIMATE

IF we had to consider astronomical effects only, we should expect to find that, travelling north or south from the tropics, we should steadily encounter colder and colder weather until we reach the poles. In practice, however, there is by no means always a steady decrease in warmth. In the first place, the climate varies according to altitude. On the equator, at a height of 8,000 feet, it would be no warmer than in England at sea-level. It has already been explained that the atmosphere provides a protective blanket round the World, stopping a large proportion of the Sun's rays, but serving also to prevent the instant escape of heat produced by those that filter through to the Earth's surface. The higher we ascend, the rarer the atmosphere becomes, with the consequence that, at great heights, any heat produced by the Sun's rays escapes so quickly that an object has no chance of becoming warm. That is why snow on high mountains does not melt: it reflects the Sun's rays too rapidly. The point at which snow and ice never melt is called the snow-line, the height of which varies from 16,000 feet at the equator

to sea-level in the Arctic regions. Now, the altitude of the land varies greatly, and, leaving mountain peaks out of the question, there are great plateaux and tablelands at such elevations that the climate is quite different from what it would be were they at sea-level. Altitude alone has, therefore, an important influence on climate.

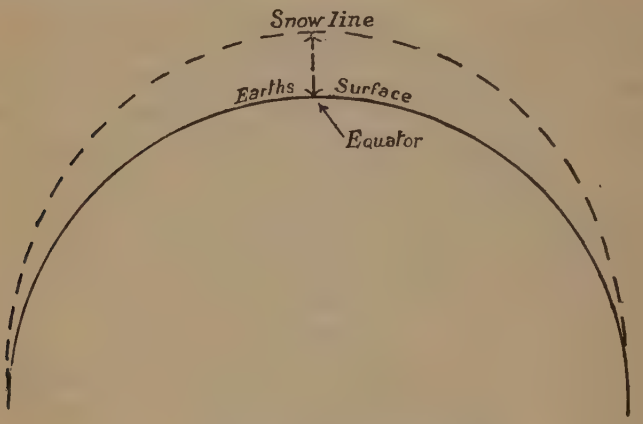


Fig. 7.—Level of the Snow-line

Diagram illustrating, theoretically, how the level of the snow-line rises from sea-level in the Arctic and Antarctic regions to a maximum height at the equator. As will be inferred from the text, however, in practice the rise does not follow a uniform curve as shown, but one in which local elevations and pockets occur, according to whether it is over land or sea, and to wind currents at various altitudes.

Another factor is the relative position of land and sea, and the effects of ocean currents. Thus, the British Isles lie in the path of the warm Gulf Stream

which tends to maintain a more or less equable climate all the year round. It is not sufficiently powerful to counteract the full effects of winter, but the warm air rising from it envelopes Great Britain and Ireland and ameliorates the severity of winter conditions. In Central Asia or Central Europe, or far inland on any continent, there is no such effect. In New York it is rather the opposite, for down the coast of the United States at that part a cold current flows ; and the severity of winter in New York is well known.

A third cause is that of mountain ranges. A range of high mountains running east and west, and at some distance north or south from the ecliptic, produces an entirely different climate for many miles on opposite sides of the range, one side receiving the full effect of the Sun's rays, while on the other the rays are distributed over a greater area. In the next place, wet winds deposit a great deal of their moisture on mountain ranges, thus reducing the amount of rainfall elsewhere ; sometimes, in fact, preventing rain from falling at all in certain localities. Even in England, rain clouds often pass over towns on the coast, so that such towns enjoy spells of fine weather when there is rain further inland. On a greater scale the same thing happens in the Andes : in parts of Chile and Bolivia rain never falls at all, and towns such as Antofagasta, on the west coast, have to obtain their fresh water supplies from springs high up in the

mountains, the water being conducted in pipes for hundreds of miles. Again, mountains determine the directions of rivers, so that on one side the country may be well watered; and on the other little better than desert land.

Vegetation is yet another factor: richly wooded country gives off as much vapour as a lake of the same area, and the cutting down of great forests, in certain parts of the World, has had serious effects upon the local climate.

Finally, there are the effects of prevailing winds to consider. Most of the great mountain ranges of the World are set at right angles to the prevailing moist winds that approach land from the ocean. As the vapour passes over the mountain-tops, much of it condenses and is deposited either as rain or snow; after which the wind, passing inland, sometimes traverses large tracts of country, on the leeward slopes of which there may be no rain for long periods. The difference between the temperature of land and sea modifies these conditions as between summer and winter. In winter, when the land is colder than the sea, there is a tendency to condensation. In summer, when the land is the hotter of the two, warm air, rising from it, tends to prevent rainfall.

In great deserts, like the Sahara and those of Arabia, the intense heat of the sands under a tropical Sun causes vapour to rise to a sufficient height to prevent the condensation of moisture over those areas,

with the consequence that rain seldom if ever falls there.

The distribution of land and sea, mountain chains, the configuration of land, and the resulting variations in climate have had far-reaching effects upon the development of life and civilization.

CHAPTER XXII

EARTHQUAKES, VOLCANOES AND GEYSERS

IN the two succeeding chapters will be found descriptions of these terrible manifestations of physical changes which the World is continually undergoing; but since earthquakes, volcanoes and geysers are interdependent, the present chapter will be devoted to a preliminary explanation of the connection between them.

We may begin, even at the cost of repetition, by picturing the World as consisting, at the present time, of a gaseous interior surrounded by a brittle shell or crust of rocks and earth scores or hundreds of miles thick which is constantly cracking and splitting.

It has already been explained how the contraction of the crust causes it to bulge and bend into upward and downward curves. This bending naturally weakens it in places, enabling portions of the fluid interior to force their way out. Such places may occur at the fractured tops of mountains or in ocean beds, and volcanoes form where the gases escape. From this it is clear that the Earth's crust is not like a boiler containing steam: it is the weight of the crust

itself that causes internal pressure. Consequently, being elastic, it could not possibly burst as a boiler might, but adjusts itself, according to its varying degrees of strength and weakness, to the internal pressure to which its own weight gives rise. To put it another way : the internal gases would lie quiescent were they not contantly disturbed by extraneous forces. If we squeeze a rubber ball, the rubber of which is weaker in some places than in others, and compress the air sufficiently, it will burst through the weak places.

Now, the outpouring of gases by volcanoes, and of hot water by geysers, tends to reduce the internal pressure and allows the crust to sink inwards in places. For a time, this sinking occurs gradually and imperceptibly ; then, suddenly subsidence occurs in a series of jerks, causing earthquakes shocks.

Thus, it is a case of constant action and reaction, and it is difficult to distinguish between cause and effect. Earthquakes may be said to be the result of volcanoes, but it is equally true that earthquakes cause volcanoes ; and that a sudden burst of activity by a volcano or a geyser is preceded by earth tremors, locally indistinguishable from earthquakes.

The greatest mountain ranges of the World denote weakness in the Earth's crust—past or present—and, generally speaking, it is along or within these lines of weakness that the severest earthquakes and greatest volcanic activities occur. Along the western coasts of North and South America, from Alaska to

Tierra del Fuego, there is an almost uninterrupted series of mountain ranges ; while another great line of weakness extends from Kamtschatka through the Aleutian Islands, the Kuriles, Japan, the Philippines, New Guinea and New Zealand to the Balleny Islands. From Mount Erebus in the Antarctic it passes northwards to Cape Horn. At right angles is another zone from east to west. Where the zones intersect, as in Central America and the East Indian Archipelago, there is the most intense volcanic activity, as might be expected. Numerous volcanoes occur in these principal lines of weakness which intersect and almost encircle the Pacific Ocean, and, while there are many other volcanic vents in the Earth's crust, it is chiefly within or along these principal lines that the World's internal heat escapes at the present time.

CHAPTER XXIII

EARTHQUAKES

IT is commonly supposed that the World rotates smoothly and evenly on its axis, very much like a steel ball might spin on a shaft or pin, but that is far from being the case. In the first place, the Earth is neither perfectly spherical nor solid. Its diameter is about 27 miles greater at the equator than from pole to pole, due to the centrifugal force of the crust as it rotates. Again, its plane of rotation is at an angle to the plane of its orbit. The attraction of the other members of the solar system, especially of the Sun and Moon, causes tidal waves not only in the sea, but in the solid crust which is distorted by these waves as they pass round the World. Their magnitude and effect cannot be computed, and it is not easy to appreciate the stresses set up. Yet probably these tidal stresses help to adjust, with more or less regularity, movements due to contraction, and to prevent inequalities from accumulating until they are suddenly adjusted in even more frightful cataclysms than those that occur from time to time.

In order to appreciate the nature and effect of an earthquake, we must remember that it is immediately due to rocks, under pressure of scores of tons to

the square inch, being sheared bodily through, when collapse takes place. This shearing action sets up tremendous vibrations, which are perceptible all over the World. The softer and looser rocks near the surface give way readily, and are shaken and displaced, overthrowing buildings and wrecking whole cities.

Earthquake shocks travel through the Earth and also round the crust, with the consequence that, when one occurs, it may be recorded three times in another part of the World: firstly, by the vibrations that travel *through* the Earth; secondly, by the vibrations that travel *round* it; and thirdly, by the vibrations that travel round it in the opposite direction.

Delicate instruments called seismometers are used for recording shocks which might otherwise be imperceptible. The three sets of vibrations may be received at intervals of as much as half an hour or more, according to the distance of the seismometer from the seat of the disturbance.

Owing to the fact that an earthquake may last any time from a few seconds to several years, and that it may comprise a single tremor or many thousands, it is impossible to say exactly how many occur during a year, but, on an average, there is an earthquake disturbance about every ten minutes, or between 50,000 and 60,000 a year. In Japan alone there are three or four daily. During the last hundred years earthquakes have been responsible for the loss of probably more than 200,000 lives. The catastrophe

TRAIN RAILS BUCKLED BY AN EARTHQUAKE

The rails on a railway near San Bruno, California, buckled by compression during the San Francisco earthquake, 1906.

A ROAD NEAR WRIGHT, CALIFORNIA

It was buckled and fissured by the San Francisco earthquake, 1906.

A Remarkable Photograph of Lava thrown out in the Form of a Fountain at Halemaūmaū, Hawaii

Generally by the time lava reaches the rim of a crater, it is free from explosive forces, and wells over in a fluid mass. Sometimes, however, explosive forces are present, such as pent-up steam, which project the lava into the air, breaking it up so that it falls in a white-hot shower. Photographs such as this are taken at the risk of the photographer's life.

By courtesy of T. A. Jaggar Esq., Hawaiian Volcano Observatory.

of 1755 destroyed the city of Lisbon in 5 minutes, and on that occasion the death roll totalled 50,000.

The extraordinary and varying effects of earthquakes have now to be considered. In some cases, there is simply an up and down motion of the ground; in others, a to and fro motion, and in others, again, a horizontal shock, with scarcely any movement at all, that suddenly tilts over buildings. Sometimes movements of the ground occur over large areas. An instance of this occurred in Assam in 1897, when 10,000 square miles of the Earth's surface shifted bodily 16 feet, and another when a road moved 18 feet sideways. In 1885, a large portion of the northern island of New Zealand was raised several feet, and at Chiloe, one of the most disturbed districts in the World, there is a rise in the ground of 1 foot annually. Frequently, however, ground level sinks, and there is a case on record where a whole district sank 29 feet without a house falling, resulting in the death of 5 persons only.

Earthquake shocks proceed in waves from the source of origin, and expend most of their force against the first ranges of mountains that may lie in their path. People who live on high hills consequently undergo unpleasant experiences on such occasions, the swaying of the hills literally rocking whole villages to and fro.

Fissures open in the ground, varying in size from mere cracks to gaping chasms 100 feet wide, 200 feet deep and a mile long, and after engulfing houses,

people and animals, close again. Often these fissures reopen later, and mangled human remains are flung out with mud, water, gases, flame and sulphurous fumes. After an earthquake in Japan in 1692, the fumes emitted caused an epidemic resulting in the death of 3,000 persons. Mice and rats are killed in almost countless thousands by such fumes, and litter the roadways (according to Professor J. Milne) as though it had been "raining rats and mice." When fissures open beneath water, as in sea, river and lake beds, great quantities of fish are killed by the poisonous gases that rise.

Mr. Milne relates another curious fact: one may be walking in the open, unconscious of any such thing as an earthquake, while houses not far off are shaking and rocking so that it is scarcely possible to walk across the floor, causing pictures to swing several feet, and the tops of the houses to move 12 inches to and fro.

It is difficult to picture what it must be to live in a country subject to earthquakes, and to think of becoming used to frequent and sudden alarms of these dreadful visitations, not knowing from hour to hour when one's house may tumble down about one's ears. Yet it must be still worse to be suddenly overwhelmed by one of them in a country that has enjoyed comparative immunity for many years.

Fire is one of the terrors that often follow. Professor Milne states that he witnessed a conflagration of 30,000 houses after one earthquake in Japan.

Rivers and lakes overflow, or suddenly dry up if cracks occur in their beds. Sometimes, the cracks close up and the water again flows ; sometimes the beds are tilted up and the rivers find new courses. In the year 1158, the Thames dried up so that it was possible to walk across it near London. In 1811, at the mouth of the Ohio River, lakes 20 miles long formed in one hour. The year 1750 in England was the most notable on record for the number of earthquake shocks felt there.

Many earthquakes, including the most disastrous on record, have originated beneath ocean beds, giving rise to vast sea waves, far greater and more destructive than any other kind, that wreak worse havoc than the earthquakes themselves. These waves vary in size : in one instance, a height of 210 feet was recorded. At the time of the great Lisbon earthquake, the sea first drew back so far as to uncover the bar at the mouth of the Tagus. About an hour after the town had been shattered, the sea suddenly returned in a series of waves 60 feet high, which swamped the city, adding to the destruction and loss of life. Ships at anchor have been swept inland for over a mile and left high and dry, and practically all shipping in the vicinity is doomed. When these mighty waves withdraw, they carry seaward everything movable in their path. So far-reaching is their effect that they are known to have traversed the Pacific Ocean, travelling at the rate of from three to four hundred miles an hour.

The effect of submarine earthquakes upon vessels

at sea is curious. It is as though the ship were struck a series of violent blows, to the accompaniment of dull rattling like thunder.

The Japanese earthquake of 1896 originated beneath the Pacific Ocean in the Tuscadora Deep, 24,000 feet below sea-level. The waves which then swept ashore were responsible for most of the deaths on that occasion. In 1868, 25,000 deaths resulted from an earthquake wave which ruined several cities on the west coast of South America.

Probably every portion of the World has been subjected at one time or another to earthquakes, and we have no proof that any country which for long has enjoyed immunity may not be the scene again of such catastrophes. Their study on scientific lines has been carried on for many years by seismologists, in the hope of finding means to forecast their occurrence and so prevent repetitions of the appalling death rolls of the past.

CHAPTER XXIV

VOLCANOES

A VOLCANO is a vent in the Earth's crust leading from the interior to the surface. Through this opening, gases, steam, dust, ashes, lava and masses of rock are projected, sometimes to a height of miles, the lighter portions being carried away by the wind. Much of the heavier materials is piled up around the opening, forming a cone, in the centre of which the escaping matter maintains a vent, whilst the remainder falls back into the crater—a cup-like cavity within the cone—to be blown up again and again, until either it falls outside, or it is finally broken up into dust. Sometimes, after a cone has been built up, the molten lava within the crater cools and solidifies, and the vocano becomes temporarily inactive. When the next eruption occurs, if the disruptive forces are sufficient, they may either blow out the whole of the solidified mass and part of the crater wall, or make new vents, so that additional smaller cones form within the original cavity. The size of the craters varies greatly, some being nearly 30 miles in circumference. Seldom, if ever, do flames issue : the red glow so often seen is the reflection of

molten matter within, from overhanging clouds of steam and gases, that gives the impression of flames.

" Explosive " volcanoes for the most part throw up ashes, dust and sections of rock, whilst those of the " Effusive " type eject quantities of lava, with intermittent blasts of steam. " Mud " volcanoes are feeble effusions of mud, a few yards in diameter and height, such as those on the shores of the Caspian Sea and in Yellowstone Park.

Some volcanoes are in a state of more or less constant activity, and seldom break out in great eruptions : others, at long intervals, display the greatest violence.

In certain places, notably in Iceland, when water finds its way into volcanic fissures, it is expelled in the form of hot fountains called geysers. An enormous amount of the Earth's internal heat escapes in this way.

Volcanoes are frequently described as safety valves to the Earth's internal pressure, but that is only a half truth. They are vents resulting from that pressure, although it is true that, so long as they remain active, they prevent more dreadful eruptions elsewhere.

There are at the present time about 270 active volcanoes in the World, of which 175 are islands or on islands formed by the bursting of pent-up gases, ash and lava through ocean beds. Instances of such occurrences, within living memory, are on record :

in the year 1891 a column of steam was seen to rise from the Mediterranean Sea, and red-hot balls of matter shot up and spluttered about on the water, hissing and raising steam. Others were thrown, spinning round and round, to a height of 90 feet, and burst in the air. Some of these balls measured 2 feet in diameter. This eruption formed an island 9 feet above the water and a quarter of a mile long; but within a few days the island was washed away.

Other volcanic islands are on a far grander scale. The eruptions persisting, great cones rose gradually from ocean depths. One of the Hawaiian group rises from a depth of over 12,000 below to 14,000 feet above sea-level, making a total height of between 5 and 6 miles from the ocean bed. Numbers of these islands have precipitous sides, owing to the rapid cooling of the lava as fast as it was ejected, in the ice-cold depths of the sea, and to the external pressure of the water. If the Pacific Ocean could be drained, its many islands of comparatively small diameter, rearing their snow-clad heads to such great heights, would present a strange and impressive spectacle.

The age of a volcano is not measured in years, but in periods or eras of time, in the same way as that of rocks. Thus, examination of the strata above and below beds of lava and volcanic ash, enables us to determine during which geological periods volcanic eruptions occurred.

In some localities, groups of volcanoes in close proximity poured forth such volumes of matter as to build up islands of great area ; such was the origin of Iceland which, from time to time has changed considerably in contour and area, portions having been blown away whilst new islands formed in the vicinity. During the eruption of 1873, Skaptar Jokul projected streams of lava 50 miles long, equalling Mont Blanc in volume.

We have thus two classes of volcanoes : those on land resulting from eruptions where the Earth's crust has bent upwards and split, and submarine volcanoes that burst through weak places in ocean beds and form islands.

Of land volcanoes, Cotopaxi in the Andes is the highest. It is 19,600 feet high from sea-level, the altitude of its almost perfect cone being over 10,000 feet. The crater is 2,300 feet in diameter, or nearly $1\frac{1}{2}$ miles in circumference. The upper portion of the cone is snow-clad for a height of close upon 5,000 feet, and at this immense altitude, Cotopaxi belches forth fire in regions of perpetual ice and snow.

The matter ejected by volcanoes includes fine dust and ash, which rise to a great height and are conveyed by winds to immense distances. Blasts of steam condensing into water and mixing with the dust form hot mud that pours over the neighbouring country—it was such mud from Vesuvius that overwhelmed the ancient city of Herculaneum. Ash falls in dense

showers over surrounding districts for scores of miles to a depth of many yards, suffocating, scorching and burning to death all living things within reach. It was under such ashes that Pompeii was buried. Although destructive of life, volcanic ash and mud are great preservatives : thus, excavations at Pompeii and Herculaneum have disclosed almost everything in a state of perfect preservation.

Scoriæ is another product : soft, spongy rock, distended and made light by gases. Pumice is another : a kind of glassy lava rendered porous in the same manner. Large pumice stones are sometimes projected long distances, and ships at sea have been caught in showers of pumice, endangering their safety. Puzzolana, from which a kind of cement is made, is a further product. Sulphurous fumes are emitted ; and vast quantities of carbon dioxide that supply one of the needs of vegetation. Certain precious stones, such as the opal, and many crystals of beautiful colours, are also obtained from the materials ejected.

During an eruption, portions of underlying rocks are torn away and cast up : blocks weighing many tons have been hurled several miles. The escape of great volumes of steam through volcanic vents generates electricity, with the consequence that eruptions are usually accompanied by vivid lightning and thunder storms, adding to the grandeur and impressiveness of the scene.

But perhaps what fire the imagination most are the

streams of lava that well up in the craters and pour down the slopes, breaking gaps in the sides, flooding enormous areas with molten rock and destroying everything in their path. Occasionally, such streams find their way, hissing, into rivers, turning the water into steam and blocking up the river-beds. Lava streams have been known to extend to a distance of as much as 100 miles, ending in the sea. When very thick, they take a long time to cool: sometimes, years afterwards, they are still red-hot a few feet below the surface. After cooling, they present a peculiar appearance, resembling masses of black, petrified snakes.

Basaltic lava is dark grey or black. In many places, it solidifies in the form of polygonal columns—nearly hexagonal in section—lying close together and appearing, end-on, like solid, rocky honeycombs. The columns are in sections that fit end to end in ball-and-socket-like joints.

When molten lava bursts through other rocks, or is deposited over them, it produces remarkable effects: for instance, it converts chalk into marble.

Krakatoa is a volcanic island in the Sunda Strait, between the islands of Java and Sumatra. For generations prior to 1883, the volcano had been inactive, and the island was covered with tropical vegetation; but in the spring of that year, indications of an impending outbreak became manifest. The first signs were earthquake shocks, accompanied by subterranean rumblings. Now, it is a curious fact that

although volcanoes nearly always give ample warning of impending eruptions, inhabitants of the surrounding country not only ignore those warnings, but go out of their way to court disaster—in spite of terrible instances of the results of such carelessness afforded by previous catastrophes. On this occasion, the warning of Krakatoa lasted so long that a party of excursionists who visited the island and climbed the volcano, were rewarded, not with the sudden death they were risking, but with the spectacle of a column of steam 90 feet wide issuing from the crater with a deafening roar.

For months the rumblings continued, increasing in intensity until they were heard for scores of miles. Dust was thrown up in such quantities that, for many miles around, the sky was obscured and the days were dark as night, save for vivid and almost incessant flashes of forked lightning; whilst houses hundreds of miles away were shaken to their foundations.

Towards the end of summer, the climax was reached when a terrific explosion blew a large portion of the island to fragments, and scattered ten cubic miles of the Earth's solid crust to the winds as dust. Rain falling through this dust formed mud which poured down in such quantities that in 10 minutes the deck of a ship 45 miles away was covered to a depth of 6 inches. The dust fell in appreciable quantities at a distance of 1,100 miles. It is said that this convulsion broke all records.

Some idea of the noise of the catastrophe may be gained from the fact that four hours afterwards it was heard 3,000 miles away, this being the time taken for the sound to travel that distance. The vibrations spread from the spot in ever-widening circles, like the ripples caused by throwing a stone into water, until they spanned right round the Earth. Then they converged until they met again on the other side, at a point diametrically opposite to Krakatoa. From that point, the vibrations rebounded, widened out and again passed round the World, converging on Krakatoa where they had originated. Even then, they did not stop, but spread out once more until at last they died away.

Such was the force of the eruption that immense volumes of dust were driven to a height of 20 miles. Here, it was caught by a wind which is believed to travel continuously round the World from east to west at that height. For hundreds of miles, the Sun was obscured by this dust which was carried many times round the World. Indeed, 2 years elapsed before the atmosphere finally cleared and the dust dropped to the Earth again.

During that period, extraordinary atmospheric effects were witnessed. To people in some places, the Sun appeared blue and the Moon bright green, and for many months after the eruption, the most glorious sunset colours ever seen were caused by the dust from Krakatoa. In England, these effects were

extremely beautiful, and in the possession of the Royal Society is a painting of one of them, the colouring of which one might well imagine to be exaggerated.

Many thousands of lives were lost owing to sea waves 50 feet high which inundated adjacent shores, dealing death and desolation at distances of hundreds of miles. The effect of these waves was noticeable half-way round the World.

In Krakatoa we have an instance of how, after lying dormant for generations, so that people have for long ceased to regard it with fear, a volcano may again burst forth with increased violence, when other vents fail to serve as efficient safety valves to the Earth's internal forces.

This eruption of 1883 converted Krakatoa into a sterile, ash-covered island, devoid of every sign of life ; but Nature immediately set about her work of restoration, and at the present time, the island is again clothed with tropical vegetation, whilst the fauna and flora include many species.

A question that naturally arises is, whether volcanoes at the present time are greater and more violent than in the past, or than they will be in the future. There can be no doubt that as the Earth's crust grew thicker, volcanoes became fewer in number, but that they increased in size and magnificence. It is also natural to suppose that in future ages, when the crust has become sufficiently thick, it will be able to

resist without distortion the lateral pressure which its own weight now causes, and that the curving will cease. As that time approaches, volcanoes will become fewer and fewer, until at last they are phenomena of the past.

CHAPTER XXV

ROCKS AND THEIR USES

WE may now briefly describe some of the principal rocks, according to the materials of which they consist, and the uses to which they are put. Many, of apparently different kinds, were formed of similar ingredients which, according to the depth at which they occur, and the pressure, heat and chemical action to which they were subjected, have assumed different characters.

Of these, argillaceous rocks consist mainly of clay, arenaceous are composed chiefly of silicious or sandy matter, and calcareous rocks are of a limy character, comprising the remains of once living creatures. Of course, many rocks consist of mixtures of these ingredients, but it will suffice to consider the three main classes. It must be remembered that beds of these different rocks alternate with each other.

Argillaceous rocks contain varying quantities of aluminium. The grains are so fine that they can scarcely be seen, even with the aid of a microscope. The qualities vary greatly. Thus, there is porcelain clay from which china ornaments are made ; pottery clay of which earthenware vessels are moulded, brick and fire-brick clay, pipeclay and fuller's earth,

containing calcareous matter, used for scouring and cleansing purposes.

Marl is hardened clay mixed with calcareous matter. Shale is similarly hardened by pressure and can be split or flaked.

Another form of clay is slate, which at great depths has been compressed to such an extent that it has changed to a hard rock. Everyone is familiar with the fact that slate can be split into thin sheets and used as a roof covering. Fig. 8 shows a bed of clay with a stratum of sand running across it. As the clay was subjected to greater and greater pressure, the

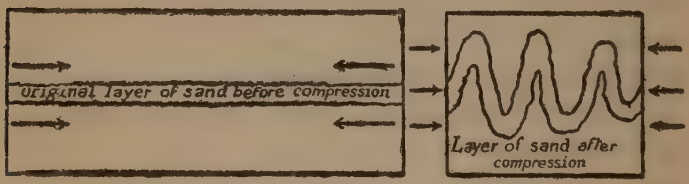


Fig. 8.—How Slate Became Laminated

This illustrates a theory of how slate became laminated. Compression taking place in the direction of the arrows caused embedded layers of sand to assume serpentine or curved forms so that as the original material surrounding it changed to slate, the particles slowly slid over each other in thin layers which although cohesive are readily separated upon relief from pressure.

width of the bed decreased and the layer of sand, being almost incompressible, assumed the serpentine form shown. This forced the particles of clay to shear against each other in parallel planes, as it changed to slate, and so to form layers or thin sheets which, however, still adhered to each other owing to

the pressure. Upon exposure and relief from compression, these sheets may be easily parted.

Under still greater pressure and heat slate turns to schist, and finally to metamorphic rock. Thus, we trace the gradations of clay from a soft, sticky substance, near the surface of the ground, to a crystalline rock at enormous depths.

Similarly, we may follow the changes in calcareous rocks. Uppermost there is soft chalk, which becomes harder as the depth increases. At lower levels, limestone is found, and this also consists largely of the remains of creatures and plants. Marble is of similar origin, but has been subjected to greater pressure, and is sufficiently hard to enable it to be polished. When crystallized and white, it is known as statuary marble.

Arenaceous rocks comprise sand and other matter of mineral origin, cemented together in solid masses. Sandstones usually consist of grains of sand bonded together by silica deposited by water, in which it was carried in solution. Conglomerate, or pudding stone as it is called, consists of masses of gravel and sand cemented together either by silica, calcareous matter or iron rust. At very great depths sandstones change into quartz.

Most varieties of stratified rocks consist of mixtures of the ingredients of these three principal classes. Their different colours are mainly due to the presence of particles of metal—especially iron.

The older and harder varieties of limestone, such as

Portland stone, are valuable as building materials. Among other notable structures, St. Paul's Cathedral, London, is built of Portland stone. Other qualities are ground and calcined for making cement, which, mixed with water, sand and broken stone, forms concrete, a magnificent artificial stone, noted for its strength and durability.

CHAPTER XXVI

WAVES AND VIBRATIONS

IT may perhaps be asked, why, in a story of the World, are included such matters as waves and vibrations, heat, light and colour? But a little consideration will make it clear that they are as essentially a part of the story as anything else, for without them the World would be but a dark, ice-bound mass, devoid of life of every description.

If you stand on a seashore towards which heavy billows are advancing, which at last break at your feet, you may find it difficult to believe that the whole mass of water is not being carried forward, and you may think that you see the waves; but that is not so: what you see, is the effect of energy imparted to the water.

If you set a cork afloat at a distance from the shore, if the whole of the water were advancing, the cork ought to come in at the same speed as the wave on which it is afloat. But it does not; it simply bobs up and down, whilst wave after wave overtakes it, and it will probably be a long time before you observe that it makes any progress at all. Yet, if the tide is rising, the cork will gradually drift on to the beach, and this shows that the motion of the waves is really

not as simple as it may seem. Something is really carrying the cork towards the shore, at a different speed from that of the waves. We have to do, then, with at least two kinds of motion in most, if not all, waves.

Those who have grasped the principle of gravitation will be aware that there is an attraction between the Earth and the Moon. And not only the Moon, but the Sun and planets, in proportion to their mass and distance, are dragging at every particle, always. But the Moon, being nearest, exerts the principal attraction, and if there were no land in the way, this would hump up the water into a wave which would race across the ocean at a speed of hundreds of miles an hour, trying to keep pace with the Moon in its apparent journey round the Earth. That is called the tidal wave. But when the tidal wave encounters land, it is diverted in many directions and in some places stopped altogether. The consequence is that it loses time and, as the Moon's influence passes, begins to die down. It is this wave that causes the rise and fall of the tide. In places where the land slopes gradually seaward, as the tide rises, the water moves towards the shore, and thus our cork is at last cast upon the beach, not by the ordinary waves, but by the tidal wave acting with them. Conversely, if the tide were receding, the cork would travel seawards, in the opposite direction from that in which the waves approached.

Now, whether we consider the tidal wave caused by

the Moon's attraction ; ordinary sea waves caused by wind ; or ripples by a stone thrown into a pond of still water, we see that they are all the result of force applied to the water.

If we tie a rope several yards long securely to a tree, and shake the other end vigorously, we cause it to undulate in a series of upward and downward wave-like curves which pass to the fixed end. Although we do not pull or push the rope, the energy we impart to it is transmitted to the tree.

Again, if we were to drop a marble exactly in the centre of a pool of water with a circular rim round it : the ripples or waves would radiate outwards from the spot where the marble was dropped in ever-widening circles. Each circular ripple would encounter the circular rim of the pool all round at the same moment, and would be reflected by the rim in a gradually decreasing circle that would ultimately converge again to the point where the marble was dropped.

The waves we have been considering travel at speeds which depend partly upon the rate at which energy is imparted to the water. Sea waves either die out by gradually expending their energy against still water, or when they break upon the shore. But if water be contained in a pipe, so that the pipe is full and the water cannot escape, and a piston be made to move rapidly to and fro against the water, the force exerted by the piston is imparted to the water in waves that cannot be seen, but which travel at a speed of nearly a mile a second.

Let us next consider an instance of waves in solids. Take a rigid steel bar with flat ends, fix it so firmly that it cannot possibly move, and place a second bar end-on to it and touching it. If we strike the other end of the fixed bar a smart blow with a heavy hammer, the second bar will be moved away from it. As the fixed bar cannot have moved, how does it happen that it moved the other? The reason is that when the fixed bar was struck, the blow set up a wave of energy that passed through the steel and expended itself against the second bar, driving

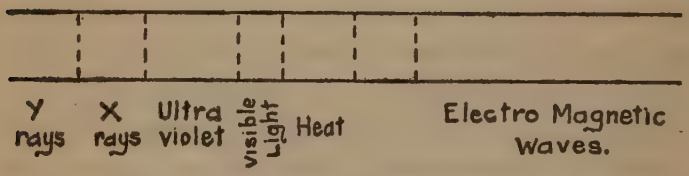


Fig. 9.—Spectrum of Ether Waves

Although shown in sections it must be remembered that ether waves merge imperceptibly, so that there is an infinite gradation from the longest electro-magnetic waves (many miles long), down to the gamma rays of radium which have a wave-length of about 1/1,600,000,000th of an inch and a rate of vibration of about 18 billion times per second.

it out of its position. The same principle applies to a little trick with pennies. Place two pennies side by side, touching each other, and say to a friend: "Touch one penny without moving it, and move the other without touching it." If he knows the trick, he will take out another penny, place it along side the others, press his finger firmly on the middle one, and

bring his own penny sharply against it when the third penny will be jerked away. Without knowing it, he will have caused a wave of energy to pass through the middle penny and expend its force against the other.

Heat, light and sound are all the effects of force travelling in waves, each kind producing a different effect upon our senses, according to the different lengths of the waves themselves.

First, take sound. You cannot make a sound, even the softest whisper, without an effort, which means expenditure of energy. If a gong be struck, it vibrates and sets up corresponding vibrations in the air that, in turn, cause vibrations of the ear drums. Auditory nerves transmit these vibrations to the brain, where the sensation of sound is produced. With each quiver, the gong hits the air and sets up ripples or waves. The denser the medium, the more rapidly the waves travel. Thus, in air, they have a speed of 1,100 feet a second; in water, 4,840 a second—equal to 60 times the speed of an express train—and in iron they travel at about 4 times their speed through water.

Light also is a sensation caused by waves, travelling at a speed of 186,000 miles a second. These have no perceptible effect upon the drum of the ear, but cause the optic nerve of the eye to vibrate, and thus the sensation of light is conveyed to the brain.

Colour, which is merely what one may term an ingredient of light, is also due to wave action upon

the optic nerve of the eye. Different colours are the result of different wave-lengths ; that is to say, that the distance between two waves producing the effect of one colour is not the same as that between two waves producing the effect of another colour.

In wireless telephony, a person speaks into the mouthpiece of an instrument. The vibration of his voice shake a diaphragm fitted in the instrument so as to allow it to vibrate freely. The movements of the diaphragm influence electric currents, which pass along wires through various other instruments to transmitting aerials, from which ether waves are projected. These ether waves spread out in every direction and set up electric currents in any receiving aerial within range. From the receiving aerial the currents pass to the earpiece of a telephone, causing another diaphragm to vibrate and to generate air waves, which pass to the drum of the listener's ear and reproduce the original voice exactly.

All light waves are invisible. A beam or shaft of sunlight, or the " pencil " of a searchlight, is only manifest when it encounters dust or moisture in the air. On clear, dry nights the beam of a searchlight appears very faintly, and, if there were nothing to obstruct it, would be quite invisible and we should only see the light either in the lantern or the projector, or where the beam strikes something.

Now, just as water is the medium through which sea waves pass, and the bar of steel was the medium for transmitting the wave of energy when one end of it

was struck, so there must be a medium for every other kind of wave, because, so far as we can tell, waves cannot pass through a vacuum. The medium for sound waves may be a solid substance, or water, or the air. But in the case of light, no medium has been discovered, although one—badly termed the "ether"—has been assumed as "filling" all space and permeating all matter.

The Sun continually pours forth rays of various kinds; light and colour rays; rays that produce chemical effects; heat rays and many others. All these are assumed to proceed as waves through the ether and, according to their different effects upon objects and upon our senses, so are they named.

CHAPTER XXVII

HEAT

HEAT may be described as a condition of matter and as a form of energy. If an electric current be allowed to flow along a wire of insufficient size, it causes the wire to become red or even white-hot. That is how light is obtained from electric incandescent lamps, the electrical energy being changed into white heat.

If heat is to do work, it must produce an effect on something. Liquids, solids and gases are all "matter" in different conditions corresponding to the distances that separate the particles of which they are composed. It is just as true to say of air that it is "matter," as of a block of steel. "Doing work" means causing a movement or displacement of matter.

The molecules of which all matter consists are in constant motion: in gases they move freely; in liquids their movement is more restricted; whilst in solids their motions are, for the most part, imperceptible, owing to cohesion between the particles.

All substances possess some heat, however little, that could be extracted by placing them in contact with something colder. If we imagine entire absence of heat in a substance, so that it is infinitely cold,

there would probably be no movement of its molecules ; but if it were then subjected to the influence of heat waves, the molecules would move and the resulting friction would produce heat.

Probably the molecules are held together by forces which act like elastic : if you stretch them too much, they break and the molecules escape in all directions. By heating a steel rod to a very high temperature it would first become molten and then change into a vapour or gas, as the molecules separated.

If a piece of ice be placed in a saucer in a warm room the heat of the air melts the ice and changes it to water. In so doing the heat actually does work, for in the form of water the molecules are separated so that they possess greater freedom of movement.

Suppose instead, that we place the piece of ice in a boiler, and light a fire under it : the ice would rapidly pass through the liquid stage and change to steam. And if the steam be conveyed by a pipe to the cylinder of an engine, it will force the piston to and fro and actuate the engine. Thus, the steam, or rather the heat, does work. It uses the energy that has been locked up in coal or other fuel and transfers it to water. This energy is called " molecular energy." In the act of doing work heat escapes and the steam becomes cooler and condenses.

In a railway track the rails are laid with small spaces between their ends, so as to allow for expansion by heat, which causes the rails to increase in length. The reason of this change is that when the heat rays

from the Sun strike the rails in summer time, they cause the molecules of which the steel consists to drive one another apart, and in winter, when the Sun is less powerful, this motion is less violent and the rails contract again. It is to allow for these variations of heat that spaces are left between the lengths of rails. If this were not done, they would buckle or bend and a train might be thrown off the rails. This property has been called the " Dilatancy of Matter," commonly known as " expansion."

Heat cannot be persuaded to flow except from a hot body to one that is colder ; in other words, it will not flow from one to another that is hotter : this leads to the great law called the dissipation or spreading of heat—it tends like water to a uniform level, and when that is reached, it will do no more work. It is the same with all forces : it requires what is termed a difference of potential to render them active. For instance, water only turns a mill-wheel because some of it is at a higher level, and tending to fall. We cannot see these tendencies to fall, but we can measure them by the effects they produce. Thus, if we place ice in warm water, heat leaves the water and enters the ice until it melts and all the water is of the same temperature, and then nothing further happens : the heat has done all the work possible and will do no more.

At one time, it was supposed that heat was a kind of invisible fluid that enters into substance. If that were the case, it would possess weight, and when a body is made hot it would become heavier. But it has never

been found that heat perceptibly increases the weight of a substance.

Everything in Nature, every particle, molecule, atom and electron, is in continual motion. If those particles never touched one another, then, so far as we can tell, there would be no such thing as heat. But as a matter of fact, in whirling about they continually strike against each other and, with each encounter, heat is generated. If we repeatedly strike a piece of cold iron with a hammer, it will become hot. Even rubbing two materials together makes them warm: for example, two sticks rubbed together in a certain manner generate enough heat to light a fire. In this manner we convert energy, stored in our muscles (which are like tiny heat engines) into heat.

From the Sun heat waves are continually streaming forth into space, but some day this process must come to an end, and all the sources of heat throughout the tract of space occupied by our solar system will be dispersed.

CHAPTER XXVIII

LIGHT

LIGHT is the name given to the sensation experienced when the optic nerve is excited. This nerve connects the retina, a kind of mirror behind the eye, with the brain.

But the sensation of light does not depend entirely on the retina, because, if we shut our eyes and rub the eyelids, or even if we strike our head against a solid object, the sense of light is produced. A familiar expression for this effect is "seeing stars." The late Professor Sylvanus Thomson told how by placing his head in a powerful magnetic field (between the poles of an electro magnet) he experienced the sensation of light. Light, then, is the effect of some object, sending out invisible rays, upon our eyes.

When we see the stars (not those above referred to !) it is clear that there must be some connection between them and the brain, and that it must extend beyond the optic nerve. This has led to three different explanations of light. According to some ancient Greek philosophers, small particles proceeded from the eye to the object seen. How they made their report and returned with it to the brain was not very

clear, so that this explanation was no more than a guess.

Sir Isaac Newton believed light to be caused by small particles coming from the object seen and striking upon the retina, the " image " they produce being transmitted by the optic nerve to a " centre " or " ganglion " in the brain. He was the first to prove that light is composed of various colours which always appear in the same order—violet, indigo, blue, green, yellow, orange and red, which, when united, appear as white light. The colours are due to different wave lengths and rates of vibration of the particles in the object causing the light. The light from the Sun is slightly yellow, and from the stars red, green, etc., according to the heat and composition of the star from which the light comes. The hottest stars, owing to the great agitation of their particles, give the nearest approach to white light.

A third explanation of light is that it is caused by a wave motion or vibration of the invisible ether.

The waves excited by a stone falling into water move outwards from the point where the stone struck, in a series of circles in one plane. But if a disturbance —say an explosion—took place at a point deep down in the water, the waves would move outwards in every direction, so that, could they be seen, they would appear as so many extending globes one outside another. That is how ether waves travel.

Light travels through air at a speed of 186,000 miles a second. Through water it travels at 138,000

miles a second, and through glass at 124,200 miles. These speeds are so tremendous as to be almost beyond comprehension: it would take an express train, going at a good 60 miles an hour, practically 130 days and nights without slackening speed to travel the same distance that light speeds through in one second.

When searchlights sweep the sky at night, the beams or "pencils" of light sometimes appear more distinctly than at other times. On very clear nights it is difficult to perceive them at all, and all that is seen is a reflection from clouds overhead. If the air were perfectly clear and free from dust and moisture, the rays would be invisible and would reach to much greater distances. It is dust and moisture upon which the rays strike that makes them visible. From this it will be gathered that it is only when light rays encounter something tangible that their effect is perceptible.

Light is reflected from most bodies, especially from those with polished surfaces, but only a portion of it. In the case of glass, nearly all of it passes through; in air, much is absorbed; whilst X-rays (invisible but exceedingly powerful light rays) can only be reflected by crystals.

The slope or angle at which light is directed on to a mirror is called the "angle of incidence." The angle at which it is reflected is called the "angle of reflection." At whatever angle it strikes a body it is reflected at the same angle.

Although light can be produced in a great variety of ways, it always constitutes the same spectrum of rays. The colours we see are only a portion of this spectrum, and it may be compared with a piano of which we know only the middle octave. There are colour waves by which our eyes are not affected, just as there are air waves to which our ears will never respond.

When light comes from such vast, luminous bodies as the Sun, a large portion of it is cut off and absorbed by vapours or gases surrounding the source of origin: this produces dark bands in the spectrum (that may be compared with the whalebone stays in a fan because the light is stopped by them), and shadows are thrown on the colour-scale. As the fan opens out or shuts up, these bands separate or come closer together, and anything that moves or affects the light in its passage from the Sun to our eyes causes these changes in the position of the bands. Invisible rays constitute what might be termed upper and lower octaves in the spectrum.

Many creatures can produce light, such as glow-worms, certain animalculæ and fireflies: such light is called phosphorescence. If light dies away when the rays exciting it are removed, it is called fluorescent.

Among the heavenly bodies, the Moon and the planets shine by light reflected from the Sun, but the stars and nebulæ shine by their own light.

Each burning gas or substance has its own spectrum,

because every element produces only particular wave-lengths without encroaching on other wave-lengths, and any individual gas will only absorb or stop the radiation of its own wave-length, whilst permitting all the other waves or colours to pass.

What a boon it would be to enthusiasts were broadcast transmitting stations and wireless receivers able to discriminate so delicately, and to keep distinct and separate every wave-length generated !

This distinctive property of gases is the basis of what is known as spectrum analysis, and has led to marvellous discoveries in astronomical science that could scarcely have been conceived without its aid. The ramifications of the subject are far too deep to deal with here, but two at least may be mentioned. One is that from them we know that the elements constituting the Sun and other stars are the same as those that go to make up our World : the other is that we are able to tell whether any particular star is approaching or receding from our solar system.

When light moves from one " medium " to another, the " rays " are bent, as when a stick is plunged into water and appears bent from the point where it touches the surface of the water. The effect of twilight—the interval between sunset and darkness—is due to a corresponding cause. The Sun's rays are bent partly towards us after the Sun has passed below the horizon. This bending is called refraction and

depends on the density of the "medium" encountered. In countries near the equator, twilight does not last so long, because the Sun's rays have not so much air to travel through, since they do not slant so much as in countries nearer the poles.

CHAPTER XXIX

SOUND

SOUND is a sensation—the effect of air waves acting upon a stretched membrane called the tympanum or eardrum, causing it to vibrate, this vibration being communicated by auditory nerves to the brain, where the sensation of sound is produced. In other words, sound does not travel at all, as many people suppose, but is the effect of air waves upon the ear drum.

To a person " stone-deaf " from birth, " sound " is a meaningless expression, for the simple reason that his aural apparatus is defective and will not respond to air waves any more than an untuned receiver will respond to wireless transmission.

A speaking tube is merely a pipe containing air. If we speak into such a tube, vibrations produced by the voice travel through the air within the tube, but the waves, being separated from the surrounding atmosphere, cannot expand in all directions : their force is concentrated, so that two persons, so far apart that they could not hear each other in the ordinary way, could converse quite well through such a tube. If, however, there were no air in it, they could not hear each other at all. Again, sounds of a certain character

are extremely painful, while very powerful air vibrations will break the drum of the ear. Place two tuning forks a short distance apart, strike one of them and it will generate waves; the other, acting as a receiver, will respond and begin to vibrate in sympathy; this is perhaps one of the simplest proofs that sound is the result of force, because it actually causes the second tuning-fork to vibrate.

A hill, or a group of hills, of certain formation will reflect sound waves, changing their course, and in some cases, throwing them back upon the spot where they originated, producing an echo. Thus, a shout may be heard again after an interval during which the waves have travelled to the hills and back again. In some instances, portions of the waves are reflected to other points and thence back to where they were produced, so that the echo occurs more than once. There are places where it is repeated fifteen times.

When a piano or a harp is played, the difference in the notes is caused by the varying speed of vibration of the wires struck or pulled. A thick wire vibrates at a different rate from that of a thin wire, and a short wire from that of a long one. As they vibrate, they strike the air, setting up waves of differing strength and wave-length. As a wire vibrates more and more feebly, it strikes the air more gently, and the note becomes softer until the wire comes to rest, and the sound dies away.

Here is another remarkable fact: it would be possible to generate two sets of similar air waves,

either of which would produce a series of sounds, but which, at certain points, would neutralize each other, so that there would be momentary silence.

It may appear a startling statement to make, but the energy that results in sound might, under different conditions, produce light, heat or electricity. It just depends upon the kind of waves set up by the original disturbance and how the receiver is attuned. The waves that produce sound are called sonorous waves, and even these vary enormously. A low whisper is conveyed by waves of which there may be as few as 16 to a second, whilst a sharp hiss is conveyed by waves of which there may be over 16,000.

It is because sound waves travel so much more slowly than those of light that the flash of a gun fired, say, half a mile away, is seen 2½ seconds before the report is heard, and that flashes of lightning are often observed several seconds before the thunder is heard.

CHAPTER XXX

X-RAYS

WHAT are X-rays ?

It is always a puzzle to those who have not studied in scientific schools why it is that scientific men do not answer what appear to be simple questions in a few simple words.

Suppose a South Sea Islander who had never seen a cricket match, or even a bat or a ball, were suddenly to ask you : " What is cricket ? " you would find it much easier to explain by describing what cricketers do than by attempting to define the game, as it might be defined in a dictionary. If you simply replied that cricket is a game played by two teams with bat and ball and wickets, the South Sea Islander would be none the wiser. To make him understand, you would have to describe the bat, ball and wickets, how the wickets are placed, how the ball is bowled, how the bat is used, how the runs are made, how the teams are placed, what the aim of each player is, and how the runs are counted. And by the time you had patiently explained all this and made him understand, you would have used a great many more words than if you had read him a mere definition of the game.

So it is in science. If we were simply to give a definition of X-rays, it would be in scientific language. You would be none the wiser, and your first question, "What are X-rays?" would be followed up by fifty others. First then, we will explain how X-rays are produced; secondly, what they do; and then what they are.

Before electricity can flow as a current, there must be a conductor along which it can pass. The best conductors are the various metals, of which copper is one. Substances along which a current will not flow at all, or only with great difficulty, are called non-conductors or bad conductors. Thus, celluloid, wood, glass and dry air are non-conductors. If a copper wire, through which a high voltage electric current is flowing, be broken and the ends separated far enough apart, the current will no longer flow. But if the ends be brought near enough together, the current leaps across the gap as a spark, the air offering so much resistance to the current that it becomes hot.

Supposing we take a glass tube a few inches long, insert at each end a wire, seal the tube so that it is air-tight, and connect the two ends up to a Wimshurst machine or to an electric sparking coil. No current will flow, because it would have to pass through the air. But if we begin pumping air out of the tube electricity will gradually appear, not as a crackling spark, but as a luminous shaft of light. The more air we pump out, the more brilliant will the shaft of light become.

Photo by *John Trotter, Glasgow*

AN X-RAY PHOTOGRAPH

On the middle finger there is a real diamond ring; the stones are quite transparent to the Röntgen rays. On the fore-finger is an imitation diamond ring; the stones are quite opaque to the rays. Other points of interest are explained in the text.

But after a certain degree of vacuum is reached, the light would begin to fade until, if we could pump out every vestige of air, so as to create an absolutely perfect vacuum, the light would disappear, because electricity will not pass through a vacuum. Such glass tubes, called Geissler tubes, are made of various shapes and colours, and beautiful effects can be produced from quite a small apparatus.

In the year 1875, Sir William Crookes was experimenting with rather more elaborate tubes, with little plates, called electrodes, attached to the wire terminals inside them. One of these plates forms the terminal of the anode (up-going) stream, and the other the terminal of the cathode (down-coming) stream or current. Sir William made the discovery that, when nearly all the air was exhausted from a tube, a beautiful golden-green light surrounded the cathode, different from any other kind of light known. The rays streamed away from the cathode in parallel lines. He found that they could be drawn on one side by bringing a magnet near them, and that they exercised such a bombarding force against anything opposed to them that light objects were actually moved along by them as by a blast of air.

He then made a cathode cup-shaped, so as to focus these cathode rays, as they are called, and found that when focussed upon glass, they melted it and even charred a diamond, so great was the heat.

Twenty years later, in 1895, Professor Röntgen,

when experimenting with a Crookes' tube, as the glass tubes came to be called, discovered that, whilst the tube was covered with black cardboard, a piece of chemically prepared paper (barium platino-cyanide paper) appeared luminous, even when held at a distance of 6 feet away. This showed that invisible rays were penetrating the cardboard and producing an effect upon the paper.

Following up this discovery, a tube was made with another disc fitted in the middle, and at an angle, on to which the cathode rays were focussed. The bombardment of this disc, or anti-cathode as it is called, generated X-rays.

Now, whereas the cathode rays discovered by Sir William Crookes will not even penetrate glass, X-rays will not only pass through glass, but through any ordinary solid materials, except lead.

The whole World was astonished when Professor Röntgen showed that by means of X-rays (or Röntgen rays) he could photograph the bones in a human hand. But what enormous strides have been made since then! Crookes' and Coolidge tubes are now made by which X-rays of such power are produced that they will penetrate 12 inches of wood. They will show up a piece of iron embedded 8 inches in aluminium, and penetrate solid steel so that 4 inches beneath the surface a hole in it may be detected, whilst the bones of the foot can be seen without taking off one's boot.

We know that by holding up our fingers to a strong

light, the light penetrates the skin and soft flesh so that we can almost see the bones. If a human hand were exposed to the most powerful X-rays, it would appear like a mist. For this reason, rays of different powers are used according to the density of the substance which is to be examined. The more air is exhausted from the tube, the more powerful the rays become, and the greater their penetrating power.

The object to be examined is placed in the line of the invisible rays, and a fluorescent screen (a chemically prepared plate) on the other side of it. The rays penetrate the object and pass through it on to the screen, which they render luminous. By this means, the object appears on the screen as a shadow, varying in density according to the density of different parts of it through which the rays pass. Thus, in examining a hand or leg, for instance, in which a bullet is embedded, the flesh, through which the rays easily pass, appears faintly; the bones as darker shadows and the bullet black—since the rays do not pass through lead. X-rays also affect photographic plates precisely as light does, and photographs obtained by their aid are known as radiographs.

In Chapters I and XXVII it was explained that matter consists of atoms, and atoms of tiny planetary systems of protons and electrons. Also that in between the atoms are free electrons, the flow of which constitutes an electric current, which, therefore, may

be said to consist of a torrent of electrons. When, as in the case of cathode rays, such a torrent strikes the anti-cathode in a Coolidge tube, it does so with such force that waves of tremendous energy are generated, and these are called X-rays.

CHAPTER XXXI

PRECIOUS STONES AND METALS

IT has already been explained how loose, sandy matter resulting from the disintegration of igneous rocks, lowered to great depths by movements of the Earth's crust, subjected to pressure, heat and chemical action, finally changed to metamorphic rock, some of the ingredients being crystallized in the process. Most precious stones are simply crystallized rock formed in a similar manner, although we cannot explain their distribution and why some are of such rare occurrence.

A diamond, the hardest substance known, consists of carbon—the same material of which a piece of anthracite coal is composed—but it is carbon that has been crystallized. Coal, as we know, was formed from vegetable matter that changed gradually to carbon ; but we do not know the origin of diamonds. They are found in several parts of the World, including India and Brazil, but chiefly in the Kimberley mines of South Africa, where they occur in a conglomerate consisting of blue clay interspersed with small stones and grit. In some parts they are found in gravel deposits. Fabulous sums have been paid

for single specimens, and the disputed possession of a fine gem has, on occasions, resulted in war. Very few stones exceed 100 carats in weight, a carat being about 4 grains troy. The famous Koh-i-noor, valued at from £500,000 to £3,000,000, originally weighing 186 carats, was cut down to 106½ carats, whilst the Cullinam specimen weighs considerably more. It is, however, impossible to calculate the real value of such specimens, since they are never bought or sold.

But it is not only as ornaments that diamonds are used. Small, inferior stones, set in tools, are used for cutting glass and other diamonds; also in the edges of boring tools for grinding holes through rock. Diamond dust, which may be described as the refuse of the gems, is worth ten times its own weight in gold —merely to use for polishing the cut stones.

Many precious stones consist of crystallized alumina (a kind of clay), their colours being due to small quantities of iron or other metals that were present in the clay before crystallization took place. Among these are the ruby, with its rich red colour; its sister gem, the sapphire, of exquisite blue varying to white; the green emerald; the purple amethyst; yellow topaz and the opal—a form of flint.

In what a different manner a pearl is produced! Secreted within its shell by that lowly denizen of the sea, the oyster, ever growing in size and beauty, at last it may be strung with others into a necklace of almost priceless worth.

Thus it would seem that Nature, not content with supplying mankind with all the necessaries and other luxuries of life, even panders to the whims and fancies of the fair sex by providing them with jewels of exquisite beauty and purity.

It is a curious reflection, and one of the surest indications of instinctive rivalry in human nature, that all these gems are prized merely because of their rarity. Were diamonds as plentiful as glass, and glass as scarce as diamonds, glass necklaces and tiaras would be the favourite adornment of feminine beauty, and the use of diamonds would be confined to glaziers' tools, boring tackle and other purely useful purposes.

The various metals, for the most part, occur as ores; i.e. mingled with rocky matter from which they are extracted by complicated processes. Occasionally, however, they are found in a pure or, as it is called, "native" condition.

Let us start with gold—the most precious metal in common use (or rather in common use before the war of 1914–1918). Gold is the metal chosen by common consent as the medium for settling trade balances between nations, for the simple reason that it is the rarest metal obtainable in sufficient quantities for that purpose—although in other respects it is one of the most useless. In South Africa it occurs in quartz veins running through other rocks. In Australia and other parts it is found as fine grains (gold dust) in the beds of streams, and occasionally as "nuggets"

weighing anything up to 2,200 ounces. In the year 1910, the World's production of gold amounted to nearly £100,000,000, of which about one-third was produced in the Transvaal. Although gold occurs in almost every country, it is only in a few that sufficient quantities are found to pay for its extraction: when it occurs in quartz, it needs one-quarter of an ounce of gold per ton of rock to defray the cost of the process. A return of 1 ounce per ton is good, but in exceptionally rich seams twenty or thirty are sometimes obtained. Gold is $2\frac{1}{2}$ times as heavy as iron.

Platinum is an even more valuable metal than gold. Found in the Ural Mountains, Brazil, Borneo, California and Australia, on account of its rarity and valuable properties, it is only employed for purposes other metals would not serve. Owing to the fact that it expands with heat and contracts to the same extent as glass, it is largely used as filament terminals in electric lamps. Platinum weighs $2\frac{3}{4}$ times as much as iron, and 9 times more than aluminium.

Still rarer than platinum are certain other metals, the names of which are less familiar. Of these, Osmium is interesting, for it is the heaviest known substance, being 5 per cent heavier than platinum.

Silver is occasionally found pure in Nature in the form of crystal threads twined round pieces of rock, but for the most part occurs as an ore. Sometimes the same ores contain tin, copper, lead or iron. The annual value of silver produced throughout the world is about

£75,000,000, of which the United States and Mexico contribute more than half. Silver is 1¼ times as heavy as iron.

Copper occurs as an ore, although occasionally it is found pure. Near Lake Superior, blocks of the pure metal have been discovered weighing as much as 800 tons each. The United States produce about half the World's supply.

Aluminium is one of the lightest of all the metals, being only 2½ times heavier than water, less than one-third of the weight of iron and one-ninth of that of platinum. It is extracted from certain kinds of clay —more especially bauxite. It is soft and easy to work, and on account of its great lightness is invaluable for many purposes, such as the construction of aircraft, where it is essential to save all weight possible. It is produced in the United States, France and Great Britain.

Tin ore occurs as crystals, or in veins in very old rocks, particularly granite and gneiss. In other cases upheaval and disintegration caused separation of the grains which are found in river-beds, or where they have been deposited by water. Tin is not quite so heavy as iron. Melted with copper it forms bronze, and, by reason of its non-corrosive property, is largely used to coat articles of iron to prevent them from rusting. The principal source of supply is the Malay Peninsula, but it is also mined in Cornwall and other places.

Mercury (quicksilver) is found in its native or pure

state, and also as an ore known as cinnabar. In some rich quicksilver mines it occurs in drops that collect and run together in pools. In addition to its employment in the manufacture of looking-glasses and thermometers, it is used for many other purposes, such as explosives and medicines. When heated, its vapour is extremely poisonous. This metal possesses the property of amalgamating or mixing with certain other metals—particularly gold and silver—forming what is called an amalgam or alloy, which property enables it to be used for extracting grains of gold and silver from their ores. Occasionally, it is found united with silver in a solid, brittle mass, but when the amalgam is heated the two metals separate. Mercury is $1\frac{3}{4}$ times as heavy as iron, which will float on it like cork on water. It can be boiled and vapourized or frozen solid.

Iron occurs principally as an ore, sometimes in the vicinity of coal measures, as in England, although blocks of pure iron weighing tons have been found. It is separated in blast furnaces from the rocky matter with which it is usually found mixed, and is then cast into blocks known as "pig iron," from which cast iron, wrought iron and the various qualities of steel are made. The World's production of pig iron in the year 1911 amounted to about 65,000,000 tons, of which Great Britain produced nearly 10,000,000 tons, the United States 24,000,000 tons and Germany 15,000,000 tons. It is supposed that the remains of animal or vegetable matter assisted in its formation.

Pure iron weighs about 480 pounds per cubic foot—nearly 8 times the weight of water.

Lead, often found in silver ore, so that it is difficult to say whether it is a silver or lead ore, comes from Spain, the United States, Germany, Mexico and Great Britain. Its weight is $1\frac{1}{2}$ times that of iron.

Zinc, which is lighter than iron, is produced in Germany, Belgium, Silesia, the United States and Great Britain, and is used for coating articles of iron and steel to protect them from the weather, while brass is made by mixing a certain proportion of it with copper.

This completes the range of the principal metals of commerce with which Nature provides Man for his use and convenience, and we may close this chapter with a further reference to gold and iron. These two metals stand out in extra-ordinary contrast. Of all the metals in common use, gold is the rarest and most precious, iron the cheapest and most plentiful; yet from the point of view of utility, gold is the least, and iron by far the most useful. If all the gold on Earth were suddenly to disappear, the World's work could go on almost unhindered. But if all the iron were to vanish, civilization would be thrown back centuries and would never recover. If all the iron were to be replaced by gold, it would be worthless! Boilers would burst, engines would fall to pieces, buildings would tumble down, bridges would collapse under their own weight, and not a dynamo or electric motor could be made to work. Yet, under natural

conditions, gold is almost indestructible, whilst iron rapidly oxidises. If we were to place a bar of gold and a bar of iron of the same size, say, one-eighth of an inch thick, side by side exposed to the weather, and leave them undisturbed, in a few years the iron would have rusted away, but the gold would be found unaltered.

CHAPTER XXXII

COAL AND OIL

OF the natural products of the Earth, none is more important than coal, for it is one of the two chief sources of artificial light, heat and power. During the Carboniferous period, when the Earth's crust was still warm, vast forests of trees and other vegetation probably grew so rapidly that a few days' growth may have quite altered the appearance of great areas. Great belts of such forest-covered land were submerged, sediment was deposited above them, and fresh forests grew over the old ones, to be in turn inundated. In other instances, storms tore down trees and vegetation and carried them down to lower levels, where they also were submerged. In time, these submerged forests sank to lower and lower levels and sedimentary rocks formed over them, with the sea above. Down they sank to depths of thousands of feet, and the tremendous weight of the rock and water crushed and compressed the layers of vegetation, while the great heat effected chemical changes, until at last the vegetable matter was converted to coal.

Then, other movements of the Earth's crust lifting

the beds again, they were, in some instances elevated with mountain chains, in which coal is now found thousands of feet above sea-level. In yet other cases, the beds are still below the sea, and in some parts, as in Cumberland, coal is actually mined beneath the sea bed.

Thus, through untold ages, Nature patiently worked and laid down these vast stores of energy without which the World's commerce would abruptly cease.

Not only in the Carboniferous period do we trace the origin of coal: it may be said that even to-day Nature is preparing new beds in some parts of the World. But the process became slower and slower as the Earth's crust thickened and cooled. In some countries—notably in Canada—there are vast quantities of peat which, in the course of time, might change to coal, although probably it will all be used up as fuel before then. Peat, which consists of a brown mass of fibrous matter, does not give out nearly as much heat as coal, and sends forth a great deal of smoke. From this, the next stage in the history of coal is lignite, half-peat, half-coal.

The first use of coal on a systematic basis is believed to have been made by the Greeks, about 100 years before the Christian era. In Great Britain it began to be mined on a considerable scale about 600 years ago, at first only at small depths below the surface of the ground, for it was not until after the discovery of steam power that it became possible to mine it at

depths of half a mile, as is done now. In some countries—notably in the United States—it occurs as outcrops in hilly districts and can then be procured far more easily and cheaply than by mining as in England.

Seams of coal, which vary greatly in thickness, are found between strata of rock called shale, from which shale oil—a product of the original vegetable matter—is obtained. Sometimes the seams are only a few inches thick: sometimes 30 feet. In China it is believed that there are seams 200 feet deep, but a common thickness is from about 2 to 7 feet.

Coal varies in quality according partly to its age, but probably more according to the heat and pressure to which it has been subjected, its heating value depending upon the proportion of carbon in it. The best anthracite contains from about 92 to 95 per cent of carbon; good bituminous coal about 85 per cent; lignite 60 to 70 per cent; and peat (which is in a transition stage between vegetable matter and coal) about 50 to 60 per cent.

In the year 1860, the World's output amounted to 134,000,000 tons. Of this, Great Britain produced half. Fifty-one years later, in 1911, the output was 1,000,000,000 tons, of which Great Britain produced about one quarter, the United States nearly half, and the rest of the World the remaining quarter.

At certain intervals, estimates are made of the total amount of coal in the World, but, in spite of the enormous quantities used, the discovery from time to

time of new coalfields shows all such estimates to be unreliable; indeed, the estimates themselves vary too greatly to be of any practical use.

The greatest coal-producing countries to-day are the United States, England and Germany.

In petroleum we have what may be described as the counterpart of coal. The name is derived from two Latin words "petra" meaning stone or rock, and 'oleum" or oil, from the fact that it is a mineral oil, as distinct from that obtained from vegetable matter to-day. It is quite possible that petroleum was known in some countries long before coal, for in the Old Testament reference is made to oil obtained from rocks, and, although petroleum is usually found at considerable depths, occasionally it rises practically to ground level.

As a fuel for commercial purposes, petroleum has only been extensively used for about 60 years. Its history is not so easily traced as that of coal, but one theory is that it results from the decomposition of marine vegetation, such as seaweed, or even fresh-water organic matter brought down by rivers and deposited in the sea. Another theory is that it consists of the fatty remains of microscopic sea creatures. As in the case of coal, movements of the Earth's crust lowered the deposits, some of which, again, were subsequently elevated; curvature of the stratified rocks formed basins or pockets in which the oil (in the meantime undergoing chemical changes) was retained, and in which it is found.

In some cases, petroleum contains a great deal of spirit; in others, scarcely any. By heating it, a light spirit, petrol (or as it is termed in America, "gasoline"), is distilled; whilst the residue, heated to a higher temperature, yields paraffin (kerosene). By repeating the process and varying the temperature, the various grades of motor spirit, lighting and lubricating oils, are separated. What is finally left is known as heavy fuel oil, a dark greenish-brown substance resembling treacle in appearance, which is used for driving ships, locomotives and other engines, being forced into the furnaces or cylinders, under great pressure, in the form of fine spray.

Petroleum is found in many countries—principally in the United States, Mexico, Roumania, Mesopotamia, Russia, Dutch East Indies, Galicia, Egypt and Trinidad.

From time to time scientists warn us that the day will come when the World's store of coal and petroleum will be exhausted. In our use of these two wonderful products of Nature, probably not more than half their available value is utilized. Thus, of the 35,000,000 tons of coal annually consumed in England alone for domestic purposes, the greater part of the heat and all the useful by-products are wasted, whilst great quantities are consumed by ships and locomotives in transporting it from the pit's mouth to our homes. Nearly all this waste could be avoided by using the coal economically on the coalfields for generating electric current that could be distributed throughout the

country. Imagine the conditions under which our descendants would live, deprived of artificial heat, light and power—for all the forests of the World would not fulfil for more than a brief spell the purposes served by those two great natural fuels: coal and oil.

CHAPTER XXXIII

NATURAL PHENOMENA

IF the World were a dark, lifeless, motionless body in space, one may suppose that there would be no forces at work upon it. But these are not the conditions that obtain. The Earth is constantly dissipating its internal heat, changing, however slowly, the shape of its crust and shaken almost continuously by earthquake shocks. It is subjected to great centrifugal strains as it rotates on its axis; to tidal stresses set up by the attractive forces of the Sun and Moon; and to the pull exerted by the other planets. It is unevenly heated, lighted and otherwise affected by the Sun; portions of its surface are clad in perpetual ice and snow; some are scarcely ever cold; others are subjected to great daily and yearly variations of temperature; whilst air and water continually effect changing conditions. It is said that the balancing of all these forces is so delicate that the attraction of the Moon, in unusual conjunction with some other force, is sufficient to cause a volcanic outburst.

It is a combination of such conditions that gives rise to the Earth's magnetism as between the north and south poles. A magnetic compass consists of

a small magnetized bar or needle of steel delicately pivoted. In whatever direction the bar is turned, it comes to rest pointing to the north and south magnetic poles. If a bar of steel be laid in the ground, pointing north and south, in course of time it becomes magnetized, proving the existence of magnetic lines of force.

Lightning is the passage of a charge of electricity from one cloud to another—or between clouds and the Earth. Air is practically a non-conductor of electricity, but water will conduct and, under certain circumstances, store it to some extent. When a cloud becomes overcharged with electricity, the charge is unable to escape until the cloud approaches another cloud or the Earth; when near enough, it leaps through the air, the resistance of which is so great as to cause a flash. The heated air along the line of the flash expands, then comes together again with great force, the sudden contraction causing a clap of thunder. Reverberations of thunder are caused by repeated echoes of a crash, and the time interval between a flash and the resulting sound is due to the fact that sound takes an appreciable time to travel as compared with the speed of light. Thunder is not audible for a greater distance than about 15 miles. The zigzag course of a flash is due to the charge of electricity following a line of least resistance. Sheet lightning is the reflection of lightning at a distance.

Sometimes portions of a ship become overcharged with electricity that collects in the form of luminous

balls known as " St. Elmo's Fire," which creep about and discharge into the air from the ends of yard-arms, masts and other more or less pointed objects. They have even been known to collect on the tips of a person's outstretched fingers. Ships with timber hulls are more frequently visited by St. Elmo's Fire than those with steel hulls which act as conductors, thus preventing accumulations of electricity.

Fire-bolts, or thunder-bolts, are lightning in globular form that behave in a curious and erratic manner. Occasionally they are harmless, but sometimes disperse with an explosion, causing damage and loss of life.

The following are recorded examples of the effect of lightning and thunder-bolts.

In one instance, a man struck dead by lightning was found stripped naked, with his boots torn off and carried 80 yards away : a somewhat similar experience (but with more fortunate results) befell another man, who recovered from the shock. A pair of scissors was snatched from the hand of a girl sewing ; a pitchfork was wrenched from the hand of a labourer and carried to a distance of many yards, its prongs twisted into corkscrews. A flock of sheep, huddled close together and wet with rain, was struck by lightning and 75 were killed, the lightning passing from one to another. In some cases persons have been struck without being killed, although keys, watch chains and even ear-rings have been fused. Lightning is strange and capricious in its selection and treatment

of victims. It has been known to destroy a person's clothing with no more than a shock to the owner, and in other cases to kill people with little damage to their clothes. Sometimes it kills and leaves practically no marks on the victims, whilst others are badly burnt. In the case of trees, it may merely strip the bark or a branch, or may split the trunk asunder.

When the Sun's rays strike a drop of water, they are refracted, that is to say, they are bent inside the drop, and the different colours of which the light consists are divided and reflected from the opposite side. When the atmosphere is charged with myriads of drops of sufficient size, the sum total of the refracted rays compose the curved band of exquisite colours seen in the mighty arch of the rainbow: violet, indigo, blue, green, yellow, orange, red. It is generally supposed that a rainbow can only be seen at a distance, but that is not the case: it is possible to stand at the spot where the bow rises from the ground.

A mirage is another striking illustration of refraction: distant objects really below the horizon appear to an observer to be suspended upside down in the sky.

Haze, commonly mistaken for fog or mist, is caused by winds sweeping across desert lands, raising such quantities of dust as to obscure the light of the sun, much of this dust being carried across the coast-line and hundreds of miles out to sea.

Coronas and haloes round the moon are due to light

rays being reflected out of their course by minute drops of moisture in the atmosphere.

The aurora borealis is the result of electric action between the atmosphere and the Earth. It is seen in the northern sky, appearing as an arch of light, or rather a series of arches one within another, but also in other forms. It is best viewed from places about 60 degrees north of the equator. The aurora australis is a similar effect in the southern sky.

The zodiacal light is believed to be the reflection of the Sun's light from fine dust appertaining to the Sun itself. It is sometimes seen in spring and autumn after sunset, and consists of a pearly glow rising like a portion of a lens from the horizon where the Sun has set.

CHAPTER XXXIV

RADIO ACTIVITY

THIS is not (as might be imagined from the title) a dissertation on Wireless, but an attempt to explain a few of the mysteries of what are known as radio-active substances.

If we open a text-book on the subject of radium or radio-activity, we soon find ourselves immersed in what appears to be a chaos of signs, symbols and mathematical formulæ, including Greek letters and trigonometrical functions, which not unnaturally deter most people from endeavouring to understand it, but such formulæ and calculations are not essential to a general appreciation of what is involved. Moreover, those mystic signs are merely employed for the sake of brevity. For instance, the three Greek letters α (alpha), β (beta) and γ (gamma) are used to distinguish three distinct kinds of ray emitted by radio-active substances, but they might just as well have been called A, B and C, or X, Y and Z rays. Alpha rays are helium atoms; Beta rays are electrons, and Gamma rays are believed to be ether vibrations.

To gain some idea of the extreme minuteness of the particles with which we are concerned, imagine an atom to be magnified to the size of St. Paul's Cathedral.

A vivid Flash of Fork Lightning taken over House-tops. The lightning discharge is exactly similar to the spark from an electrical machine, but on an immensely grander scale. The electricity is passing between a cloud and the earth.

DANIEL'S COMET OF 1907

From a photograph taken, on August 11th, 1907, by Dr. Max Wolf, at the Astrophysical Observatory, Heidelberg. The instrument used was a 28-inch reflecting telescope, and the time of exposure was fifteen minutes. As the telescope was guided to follow the moving comet, the stars have imprinted themselves upon the photographic plate as short trails.

Then, we should find it to consist chiefly of space in which a few electrons the size of peas revolve round a nucleus of protons and perhaps other electrons.

Nevertheless, it must be admitted that the subject is a complex one, and it should therefore be understood that the ordinary reader may, if he pleases, pass it over without serious disadvantage, leaving it to the perusal of the more serious student.

By a radio-active substance is meant one that is undergoing a natural process of disintegration, involving not merely chemical changes, but the transmutation of elements from one kind to another.

Shortly after the discovery of X-rays by Professor Röntgen, the fact that certain substances are radio-active was discovered by a French chemist named Becquerel, in the year 1896. He was experimenting with salts of uranium, which he found possessed the power of affecting photographic plates, and of rendering air a conductor of electricity. It was also found that thorium possesses radio-active properties. Uranium is a hard, white metal, the melting point of which is about 2912 degrees Fahrenheit.

About two years later, M. and Mme. Curie discovered a radio-active substance in pitchblende, a mineral containing uranium oxide.

Proceeding with their investigations, the Curies and others succeeded in obtaining radium compounds (i.e. radium in combination with other substances), and at last, in 1910, the element radium was isolated. It

is a bright, white metal which melts at a temperature of about 1292 degrees Fahrenheit.

It will be appropriate at this point to discuss some of the radio-active properties of uranium—itself an element. Uranium and its salts give off alpha and beta rays, gamma rays of comparatively small intensity accompanying the latter. The alpha rays are readily absorbed even by a gas, their range of travel is small, and their effect upon a photographic plate is negligible : the beta rays produce a far stronger photographic effect. Sir William Crookes discovered, however, that it was possible to procure uranium that produced no such effect, and that the whole of the power to do so was transferred to the residue resulting from a chemical operation. This residue he called uranium X. If, however, the two substances be laid aside for a few months, it is found that the uranium has recovered its full original activity, whilst uranium X has lost all that it possessed, and that, at any time, the amount recovered by the one corresponds exactly to that lost by the other, even although the two substances be widely separated so as to prevent the possibility of one directly affecting the other.

From this it is deduced that whilst uranium is constantly giving off uranium X, which rapidly "decays," i.e. radiates all its energy, it is also producing, within itself, a fresh supply of uranium X to replace what is lost. The explanation offered by Sir Ernest Rutherford, and the theory formulated to account for what occurs, are extremely interesting,

but too long to give here. The conclusion is that radio-activity is due to the breaking up of atoms, and that each product of such radio-activity is a new element with properties differing from those of the original atom.

The amount and rate of emission depend upon the relative amounts of the radio-active ingredients—(if one may use the word). There is thus a condition of equilibrium, but since disintegration must end at last, radio-activity also must cease, so that it is a case of what Dr. J. A. Crowther describes as "transient equilibrium": that is to say, that the relative amounts of the various radio-active ingredients remain constant, whilst slowly on the decrease as a whole.

During the changes that take place, the emission of either alpha, or beta and gamma rays causes uranium to assume different forms.

Let us now see what occurs during the process of disintegration, starting with uranium 1.

Uranium 1 emits alpha (helium) particles, and produces uranium X_1. Uranium X_1 emits slow-moving beta particles (electrons) and produces uranium X_2. Uranium X_2 emits beta particles and produces uranium 2. Uranium 2 emits alpha particles, and produces ionium. Ionium emits alpha particles and produces radium.

Radium (in its different forms) emits at least four different kinds of ray, each possessing characteristic properties. As already mentioned, three of these are

alpha, beta and gamma rays. Another has been termed " radium emanation."

The alpha or positive rays consist of helium atoms that have lost two electrons. They are easily absorbed by matter—indeed, they will not pass through more than about $2\frac{3}{4}$ inches of air. They cause intense ionization of gases, i.e. they set up in a gas systems of electrically charged particles which render it a conductor of electricity. They travel with an initial velocity varying from $1{\cdot}45 \times 10^9$ to $2{\cdot}2 \times 10^9$ centimetres per second (depending on the substance from which they are ejected) and can be deflected from their course by a magnetic field.

The beta rays produce a comparatively small amount of ionization in a gas, but are of greater penetrating power than the alpha rays. They consist of electrons (negative particles of electricity) and, except as regards velocity, are identical with cathode rays. Thus, whilst the cathode ray electrons have varying velocities up to about one-third that of light, electrons may be emitted by radium at almost the speed of light. They can be deviated by a magnetic field—but in the opposite direction to that in which the alpha rays are deflected by the same field.

The gamma rays possess great penetrating power—those from radium will affect a photographic plate after passing through 12 inches of solid iron. They cause very little ionization, are only produced by radio-active substances that emit beta rays, and are believed to be ether vibrations of exceedingly short

wave-length, and with a velocity approximating to that of light. Together with the beta rays, they are calculated to account for about 8 per cent of the energy given off by radium, this proportion being based upon their ionizing effect. Their course is unaffected by a magnetic field.

Radium emanation is a heavy, inert gas, itself an element, emitted by radium. This gas, which is about 112 times denser than hydrogen, is itself radio-active, and, in turn produces alpha particles, changing into another form of radium known as radium A. Emanation is the first radio-active product of disintegration of radium.

Radium emits alpha particles and produces radium emanation. Radium emanation emits alpha particles and produces radium A, and so on until the final product of lead is reached, polonium being the last radio-active product. This, briefly, is what takes place, although there are complications of too technical a nature to deal with here.

Readers who have carefully followed what has been stated, cannot fail to realize that here we have an apparently paradoxical state of affairs, staggering, indeed, to the ordinary comprehension. Uranium, itself an element, in the act of spontaneous disintegration, is indirectly productive of another element, radium. Radium in turn disintegrates, and emits a gaseous element, which, when freed, fires off alpha rays and produces another form of radium.

But that is not all. Uranium and radium, although

elements, can (as already mentioned) each exist in several forms possessing different radiating properties. And the ultimate product is yet another element, namely, lead. In the whole chain of radio-active changes, it appears that 35 elements are produced. Meantime, whilst emitting such (relatively) vast energy, uranium restores to itself a very great percentage of what it gives out, so that, instead of exhausting itself rapidly, it is many millions of years before lead is formed.

Let us now examine a little more closely what occurs during the process of disintegration.

An alpha particle is shot off and begins its journey with a high velocity, but immediately finds itself beset by innumerable atoms of gas, which drive it to some extent out of its course—probably as the result of mutual repulsion—until its speed is reduced to zero. But it may collide point-blank with one of the atoms. In that case, one of several things may happen. If the atom happens to be a much larger one, alpha will be abruptly stopped (much as a small boy would be stopped by charging into a big man), although it will probably set the other atom in motion. If, however, the other atom be small enough, alpha will set it in rapid motion and cause it to travel further than alpha itself would have travelled before coming to rest.

But under certain conditions, something else may happen : alpha may smash up the atom. This has been definitely proved by Sir Ernest Rutherford, who

passed alpha particles through pure nitrogen and obtained atoms of hydrogen, and it appears certain that this could only occur as the result of atomic disintegration. The chances, however, are against this happening, so that it is only a small percentage of atoms which are thus destroyed.

The β (Beta) Rays. These are electrons, on the subject of which so much has been written that it should only be necessary here to state a few less known facts concerning them. The beta rays or electrons have a much greater penetrating power than the alpha rays, and will pass through 100 times the thickness of material which will completely stop the alpha rays. On the other hand, they are deflected out of their course to a much greater extent: it is as though the comparatively large alpha particles make a charge and rapidly exhaust themselves, whilst the tiny beta particles pick out the lines of least resistance between and through atoms, and thus travel further before they are stopped. Thus we see that electrons are projected from atoms in radio-active substances.

The γ (gamma) Rays. If, as is believed, these are ether vibrations, we have in them an association with "wireless." For, like light, electro-magnetic and heat waves, we find the gamma rays in the spectrum, at one extreme end of all the known vibrations—beyond the X-rays—their wave-length being the smallest known and varying from $0{\cdot}71 \times 10^{-9}$ to 4×10^{-9} in centimetres. (A centimetre is about three-eighths of an inch.)

It must be borne in mind that the words "ether vibrations" are only used in a general sense, to cover our ignorance of how energy is propagated in space. They are not necessarily used in the sense preached by the advocates of the elastic-solid ether theory.

We now come to another consideration : a relation between the gamma and the beta rays, corresponding in certain respects to that between X-rays and cathode rays. X-rays are produced by the impact of electrons against a plate (the anti-cathode). It is supposed that a gamma ray is caused by the sudden emission of a beta particle (i.e. an electron), or by the sudden stoppage of a beta particle which had started within the material. Conversely, if gamma rays be caused to fall upon a metallic radiator, they generate a secondary type of gamma ray *and start secondary beta rays or electrons.*

We see, then, that if an electron be suddenly started or stopped, it produces ether vibrations or waves, and that if such ether waves be suddenly stopped or intercepted, they cause the emission—or, at least, the motion—of electrons. This is quite in accord with what takes place in wireless transmitting and receiving aerials, although we are now dealing with extremely minute wave-lengths of almost incredibly high frequency.

As a matter of practical engineering, it is a known and interesting fact that the action of light expedites the rusting of iron, i.e. the chemical combination of

iron and oxygen. And it will produce other chemical changes.

One frequently reads of the tremendous force locked up in the atom, and of how, could we but release it, we should have unlimited power at our disposal. Subject to that "if," many of these suggestions are not exaggerations, although they are made rather glibly and as though we are on the verge of such a discovery, whereas it must be remembered that, although apparatus has been devised in which atoms have actually broken up, it is on an exceedingly small scale.

Although, under our very noses, as it were, Nature juggles with and breaks up atoms, rings the changes with elements and performs the trick of transmutation —the dream of scientists ever since the days of the alchemists—she takes her own time over it, and a pretty long time, too, in some cases. Atomic energy is released before our eyes, and we look on half bewildered, half comprehending and vainly endeavouring to emulate such feats.

It must be borne in mind that such statements do not mean that appreciable energy could be obtained from the breaking up of a few atoms : it would involve countless numbers of them.

Subject to this word of warning, we may conclude with a few assertions which have been made from time to time regarding this potential energy of the atom.

The Curies proved that radium salt gives out

sufficient energy to melt half its own weight of ice every hour.

Newth suggests that the energy of radio-active change is probably a 1,000,000 times greater than the energy of a corresponding chemical change, when equal weights of matter are involved. One gram of radium emanation would give a total of $2{\cdot}44 \times 10^9$ calories of heat, whilst the formation of one gram of water (the most powerful chemical reaction) only liberates $3{\cdot}8 \times 10^3$ calories of heat.

Sir Ernest Rutherford estimates that the total energy of radium is many millions of times greater than that derived from burning coal—weight for weight.

Eddington estimates that if 10 per cent of the Sun's hydrogen were transformed into helium, enough energy would be liberated to maintain its present radiation for 1,000,000,000 years.

Aston gives another example: if one gram of hydrogen (equal to the hydrogen in 9 cc. of water) were transformed into helium, the energy liberated would be equivalent to $6{\cdot}93 \times 10^{18}$ ergs, $1{\cdot}66 \times 10^{11}$ calories or 200,000 kilowatt hours. He goes on to say: "Should the research worker of the future discover some means of releasing this energy in a form which could be employed, the human race will have at its command powers beyond the dreams of scientific fiction; but the remote possibility must always be considered that the energy once liberated will be completely uncontrollable and by its intense violence

detonate all neighbouring substances. In this event, the whole of the hydrogen on the earth might be transformed at once, and the success of the experiment published at large to the universe as a new star."

Such statements are made by eminent physicists and published from time to time, and are probably read with wonder—sometimes incredulous wonder. But let us see what underlies them.

The energy possessed by a body in motion depends upon its mass or weight and its velocity. The energy increases directly as the mass, but increases as the square of the velocity. Thus, a body weighing 2 pounds and moving at 10 miles an hour, would possess 200 times the energy of another weighing 1 pound and travelling at 1 mile an hour (ignoring air friction). To put it another way: theoretically, a particle weighing 1 grain and travelling at 10,000 miles a second, would possess as much potential energy as a solid mass of iron weighing 8,265 tons—say, 20 feet diameter by 128 feet long—travelling at 100 miles an hour. Or a particle weighing one-twentieth part of a grain at the same speed would possess energy equal to that of a heavy railway train travelling at 100 miles an hour. We know roughly what would happen if such a train collided with anything: if all the radio-active energy in one-twentieth of a grain of radium were instantly released, we might expect a worse result.

Radium produces, in addition to gamma rays or waves, a stream of material particles at enormous velocities: the alpha particles, if uninterrupted, would

probably travel in one second a distance equal to half the circumference of the Earth, whilst the distance covered by the beta rays would girdle the Earth eight times. If the energy represented by all the rays emitted by quite a small piece of radium during its radio-active life could be concentrated into a short period, it would be equivalent to an enormous amount of heat or work: or if a gram of radium were to disintegrate instantly, we might expect an effect resembling a great and sudden volcanic eruption—apart from the question as to whether it would start a chain of eruptions that would destroy the World.

It has been suggested that, if in radio-activity such relatively tremendous energy is liberated, in the atoms of all matter there must be corresponding energy in a quiescent state, i.e. in a condition of equilibrium: indeed, some scientists conclude that in ordinary matter there is potential energy infinitely more than sufficient—could it be harnessed—to solve all fuel problems as long as there is life on Earth. Others like Sir Ernest Rutherford take a more practical and less hopeful view.

There seems to be nothing inherently impossible in the idea of the release of atomic energy by "artificial" means, but it will involve the expenditure of energy greater than that released, much as, in order to produce electric current, we are obliged to expend more work than can be derived from the electric current produced.

Nevertheless, whether it be to the greatest physicist

or to the reader who peruses the suggestions made, the whole subject of atomic energy presents a problem of intense fascination.

Our knowledge of to-day may prove elementary to-morrow.

CHAPTER XXXV

THE MOON AND THE OTHER WORLDS OF OUR SOLAR SYSTEM

OF all the celestial bodies, the one nearest the World is the Moon. At a mean distance of 239,000 miles, she circles round the Earth once every 27⅓ days. Her diameter is 2,160 miles. The important influence exerted by the Moon on the Earth was once expressed by Sir Robert Ball, as follows: "Supposing the Moon were to be suddenly struck out of existence, the rise and fall of the tide all over the World would almost cease, ships in dock would be unable to get out and ships outside would be unable to get in, and the maritime commerce of the World would be thrown into dire confusion." The reason, of course, is that owing to its proximity to the Earth, the attraction of the Moon is the principal cause of ocean tides.

Moonlight is simply the reflection of sunlight from its surface, for the Moon is itself a dark body. Its surface is deeply scarred with many great conical-shaped hills and cavities, probably extinct volcanic craters, although some people incline to the belief that they are caused by the impact of immense meteorites that strike the surface with terrific force; for the

Moon has no atmosphere like the Earth to act as a protective screen and scatter them as dust. Some of these craters are of great height and size, measuring scores of miles in diameter. One is 134 miles across. Another is 24,000 feet high from the bottom of the crater to the top.

Although the Moon is so near, we really know very little about her, and even what we see is only on one side, for she always turns the same face towards us. Her very origin is a matter of dispute : some believe that at one time she formed part of the World, and was thrown off by a mighty upheaval.

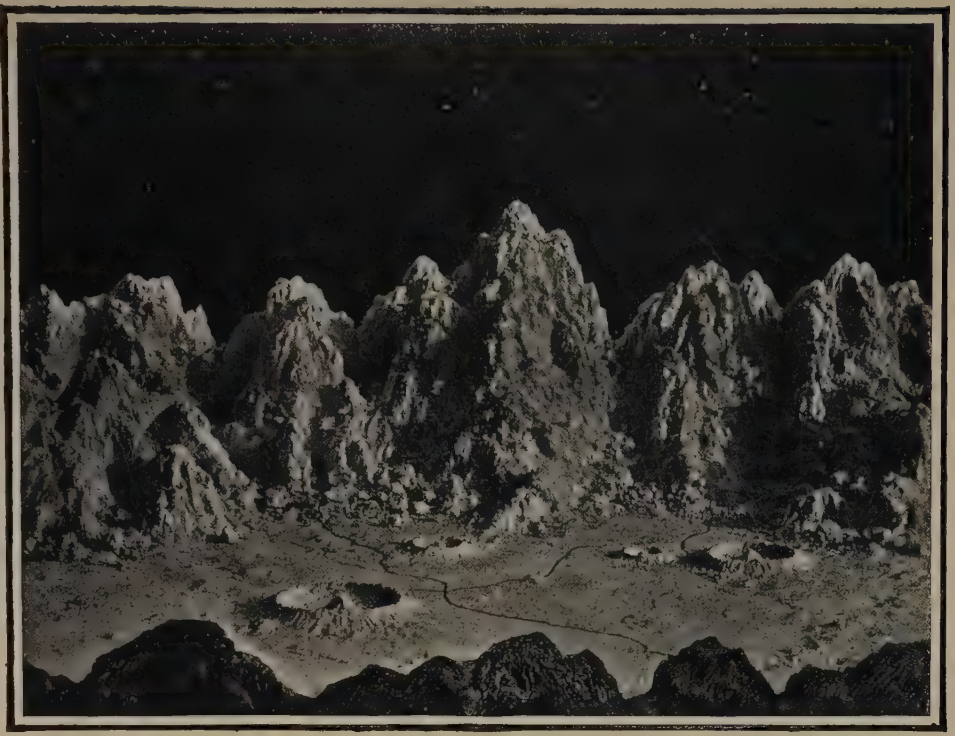
The Moon's apparent rise in the east and setting in the west is due to the World's daily rotation about its own axis. But in its revolution round the Earth, the Moon actually revolves in the opposite direction —from west to east. This may at first appear puzzling, but the explanation is really quite simple. Since the Earth rotates on its axis from west to east once in every 24 hours, it is clear that any point on its surface completes a revolution in one day. But the Moon, which is revolving round the World in the same direction in which the Earth rotates, takes $27\frac{1}{3}$ days to do so. Consequently, the Earth rotates $27\frac{1}{3}$ times whilst the Moon revolves round it once, and thus we see the Moon apparently moving from east to west whilst in reality she is revolving from west to east.

When the Moon passes between the Earth and the Sun, there is a solar eclipse, and it is sometimes asked why there is not therefore a solar eclipse every day.

The reason is that the Moon's orbit or journey round the World is not in exactly the same plane as the Earth's orbit or journey round the Sun. The planes of the two orbits are at an angle to each other, with the result that when the Moon and the Sun are both on the same side of the World, the Moon does not necessarily pass in a direct line between the World and the Sun. Again, both the Moon's orbit and that of the Earth vary. Neither the Moon in her journey round the Earth, nor the Earth in his journey round the Sun, follows always exactly the same path, with the consequence that only occasionally does the Moon pass directly between the World and the Sun, or the World directly between the Sun and the Moon. The first of these cases is known as a solar eclipse when the Sun is blotted out by the image of the Moon. The second case, when the World casts its shadow across the face of the Moon, is known as a " lunar " eclipse.

A " total " eclipse takes place when either the Earth entirely obscures the Moon or the Moon entirely obscures the Sun. This, however, is a rare occurrence, and can only be witnessed from particular localities.

The Moon's changing appearance from crescent to full depends upon the angle at which the Sun's rays strike it and are reflected to the Earth. When the World is almost—but not quite—in line between the Sun and the Moon, the Sun's rays are reflected from the full surface of the Moon, disclosing its whole image. But when they are considerably out of line, and the rays strike the Moon and are



By permission of] [*John Murray, Esq.*

MOUNTAINS ON THE MOON

If we could really visit the Moon this is what we should see.

reflected at an angle, only a part of the reflected light is seen, as a crescent, or portion of a disc, as the case may be.

Since, in the different conditions that prevail on each of them, we trace certain phases our own World has passed through, and what is in store for it in ages

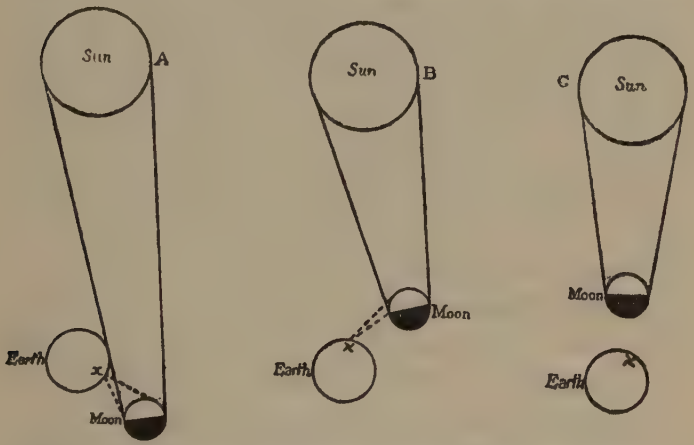


Fig. 10.—Relative Positions of Sun, Moon and World

Fig. A shows the approximate relative positions of the Sun, World and Moon when a person at X sees the Moon nearly half full. In fig. B, the new Moon is seen as a crescent from X, whilst in fig. C it is invisible. The relative sizes of the three bodies and their distances from each other are not of course drawn to scale. If in fig. C the Moon were in a direct line between the Earth and the Sun, viewed from the point X there would be a total solar eclipse.

to come, it will not be amiss to attempt a brief description of the principal planets of our solar system.

Let us begin with Neptune, the planet most distant from the Sun, which, possessing no crust like the Earth, is still in a gaseous condition. It is 34,500

miles in diameter and 2,800,000,000 miles from the Sun—30 times as far as the Earth. Its year is equal to 165 of our years and it rotates on its axis in an almost opposite direction from that in which the Earth rotates. Neptune has a moon that revolves round it like our own Moon.

The story of the discovery of this great planet is extremely interesting, for although it had been seen on several occasions, it had been mistaken for and charted as a star. For a long time astronomers had known that the orbit of Uranus was influenced by some body other than any of the known planets, and at last, in the year 1845, calculated from the behaviour of Uranus exactly when and where to look for the unknown object that disturbed it, and even what its weight must be. Then, directing their telescopes at a given time to the spot predicted, they discovered that Neptune was the offender, and, that, instead of a star, it was actually a member of our solar system. Considering that Neptune is never less than about 1,000,000,000 miles from Uranus or less than 2,700,000,000 miles from the World, this discovery is admittedly one of the most astounding in the annals of astronomy.

Next in order of distance from the Sun (nearly 1,800,000,000 miles) comes Uranus. Like Neptune, he consists of gases, and is believed to rotate almost at right angles to the plane of his orbit, but more than twice as fast as the Earth, rendering the question of day and night there a complicated one. He is

32,000 miles in diameter, and the year is equal to 84 of ours. Uranus has four moons.

Owing partly to their distances, so little is known about Uranus and Neptune that one may perhaps be pardoned for turning with some eagerness to Saturn whose disc and "rings" may be viewed through a good amateur's telescope. At a mean distance of 886,000,000 miles from the Sun—less than half that of Uranus, but about $9\frac{1}{2}$ times that of the Earth—the main body of Saturn, enveloped in gaseous clouds, is (according to Dr. Lowell) red-hot, indicating the approach of a period when a plastic shell will begin to form. At present, however, its density is only ·72 as compared with water, thus precluding any suggestion of solidity. So enormous is Saturn's speed of rotation on its axis that the centrifugal force results in a flattening between the poles equal to one-tenth of the equatorial diameter, with the consequence that, viewed with its rings edgewise on, the planet presents the appearance of a distinct oval instead of a sphere —a state of affairs alarmingly suggestive of disruption. Whilst Saturn revolves once in his orbit of 5,570,000,000 miles, the world revolves $29\frac{1}{2}$ times, so that the year there is equal to $29\frac{1}{2}$ of our years, the day being about $10\frac{1}{2}$ hours long. Since the equatorial diameter is 75,000 miles, a simple calculation gives an equatorial speed of rotation of about $6\frac{1}{3}$ miles a second, or 360 times the speed of an express train.

At one period in the history of the solar system it would appear that Saturn must have consisted of a

nebula of no mean dimensions, within the far vaster nebula of the solar system itself; for the planet claims the attendance of no fewer than 10 moons in addition to a great rotating band of meteoric matter, therein rivalling, or at least imitating on a small scale, his lord and master, the Sun. It is this band of matter, consisting, it is believed, of solid particles, that adds so greatly to the mystery and fascination of Saturn. Although, viewed edgewise, the band appears a mere streak, it is upwards of 80 miles in thickness and of immense breadth, divided up into "rings" in which "knots" have aggregated—possibly embryo grandchildren of the Sun. But it is when these knotted rings or "tores" are viewed, not edgewise, but partly broadside on, that Saturn presents a spectacle perhaps more arresting than any other celestial body—a sight, indeed, never to be forgotten.

Next comes the mightiest of all the planets, Jupiter, at a distance of 483,000,000 miles from the Sun. If all the other planets were massed together into one globe, it would not be equal to Jupiter in size. His circumference is 270,000 miles, and as the day there is a little less than 10 hours long, the equatorial speed or rotation is more than 27,000 miles an hour, the year being 12 times as long as ours. He has 5 moons and, like Saturn, is surrounded by gases beneath which is a raging furnace. Neptune, Uranus, Saturn and Jupiter are known as the "major" or outer planets.

The inner planets (in order of their distance from the Sun) are Mars, the Earth, Venus and Mercury.

But between the orbits of Jupiter and Mars there is a great space occupied by " asteroids " or minor planets, varying in size up to several hundred miles across, the five principal of which are Ceres, Pallas, Juno, Vesta and Eros. These also circle round the Sun. It is supposed that they are not globes like the other planets, but irregular in shape, because some of the larger ones are only seen occasionally, when their surfaces are at such an angle as to reflect the Sun's rays to the Earth. It is believed that, like meteorites, they are the solid portions of débris resulting from an initial catastrophe. Probably in addition to the minor planets, the space between Mars and Jupiter is occupied by immense swarms of meteorites varying in size from dusty particles to asteroids too small for detection by the most powerful telescope.

Lack of space precludes more than passing reference to two other types of solar satellites, namely, comets and meteoric swarms, both of which pursue immensely elongated orbits—more especially in the case of comets, some of which take scores of years to complete their revolutions round the Sun. Periodically the Earth crosses the orbit of such a swarm of meteors, and when the crossing coincides with the passage of a dense portion of the swarm, we witness a brilliant display of " shooting stars." At such times, but for our atmosphere, we should experience showers of meteorites that might leave few living things to remember them : as it is, however, they travel at such enormous speeds that the friction of the air burns most

of them up before they reach the ground, and dissipates them in the finest dust that eventually floats down to Earth. Many thousands of tons of such dust are added to the World in this way annually. Sometimes, however, fragments of the original meteorites actually reach the ground, and are then called "aerolites" and "siderites," but whether such fragments come from meteoric swarms or from the belt of asteroids is not definitely known.

Now whereas the main portion of the débris resulting from a collision in space resolved itself into a central sun and its attendant satellites, asteroids and meteorites consisting of solid masses which have never succeeded in uniting, represent the potential constituents of a planet which never formed. Calculations show that this was due to the jealous influence of the big brother Jupiter who apparently felt that an addition to the family circle was unwarranted!

Within this broad ring of meteorites, the outermost planet is Mars with a diameter of 4,200 miles, 141,000,000 miles distant from the sun.

Many are the conjectures as to whether Mars is inhabited: indeed, what with fiction from the pens of popular writers, and theories attributed to well-known investigators, Mars has become popularly invested with such mystery and uncertainty, that it becomes desirable to sift out what is believed to be known from what is nothing more than speculation.

According to the late Dr. Lowell there are no mountains and no oceans there, although there is

evidence of dried-up sea beds of great extent, whilst belts of what is thought to be vegetation seem to indicate the presence of a certain amount of moisture, if not actual water. The planet is apparently surrounded by a highly attenuated atmosphere containing a small proportion of water vapour, so that the strong probability is that the temperature by day is round about freezing-point, and at night many degrees below.

If, therefore, Dr, Lowell's observations and these deductions be correct, so far from Mars presenting an inviting prospect as an abode for human beings, one is rather inclined to think of that planet as in the death throes of thirst and asphyxiation, awaiting the fate that has already befallen Mercury.

Between Mars and Venus comes the Earth, whose diameter is 7,914 miles, and mean distance from the Sun 93,000,000 miles.

Of all the planets, Venus appears the most brilliant, for, although only 7,700 miles in diameter, she is comparatively near to the Earth. Her distance from the Sun is 67,200,000 miles, and from the Earth—at her nearest—only 26,000,000 miles. In February, 1921, she made one of her finest displays, after sunset and before moonrise, shining with almost alarming brightness. But sad is her fate. Venus may be compared with a beautiful woman who has " had her day." She has passed through the vicissitudes of a planet's life and is dying. Turning slowly on her axis but once in her revolution round the Sun, for

ever she faces him. Perpetually dark and frozen on one side, her other side is continually subjected to the full fierceness of the Sun's burning rays, and swept by winds rising from the hot surface, carrying moisture to the dark side and depositing it there as snow. If there be human beings on Venus, they must inhabit a wind-swept zone between the sun-burnt area and the dark and utterly cold waste. No seasons, no years, no alternating days and nights—that is her doom.

In Mercury we see not a dying, but a dead world. A world from which all water and atmosphere have disappeared. A world exposed on the one side simultaneously to the terrible coldness of space and the full fury of the Sun's pitiless rays; on the other, to perpetual cold and darkness. As Mercury revolves in his orbit, he rocks slightly about his axis, so that, if the Sun could be viewed from there, it would appear like an awful pendulum of dazzling light and fire, moving slowly to and fro in the firmament.

In Venus and Mercury, if not in Mars, we witness two of the later phases through which our own World has yet to pass.

CHAPTER XXXVI

CONCLUSION

LET us take a seat somewhere overlooking the sea, on a still, fine, summer day. The only sign of movement is the occasional flutter of a bird or butterfly, the only sound the soft, regular hush of the water, the ripple of a brook or the drowsy hum of bees. Here we find it difficult to realize that everything is in a state of continuous motion on a stupendous scale, and that every moment changes are going on, compared with which all the changes ever effected by Man are as naught.

Watch the white clouds apparently motionless in the blue sky, like mountains of snow in an azure sea, and reflect that the clear air is never still, that it is charged with vapour which it is continually collecting, carrying and dispensing over the World. That it is transporting more water than all the rivers of the World contain and pour into the oceans.

The placid sea sparkling in the Sun and softly lapping the shore in tiny wavelets is for ever at war with the land, wearing away and invading it: at times, in tempestuous mood, tearing away vast masses and flinging about, like toys, rocks weighing hundreds of tons, smashing and grinding them to mud

and sand. But for the land, a tidal wave would race round the World at a speed exceeding that of an express train. Every drop of water within sight may have been in the polar regions, frozen to ice and snow ; in the tropics ; in the uttermost depths of the ocean ; on mountain tops ; in rivers and lakes ; in the atmosphere ; and in the bowels of the Earth—driven thence miles high in blasts of steam. Portions of it may have formed part of our bodies and of plants.

It is difficult to realize that every tree, every plant, every blade of grass is absorbing the poisonous gas we exhale, giving back oxygen which is life to us, and for ever drawing water from the Earth and passing it into the air. That every vestige of animal and vegetable life must change to gases, water, salts, rocks and metals, eventually to serve as a basis for other kinds of life.

Our peaceful surroundings do not suggest that scores of great volcanoes are dissipating the Earth's internal heat and belching forth millions of tons of molten rock and burning gases from the interior of the World.

That tiny brook does not testify that thousands of tons of land are hourly swept by mighty rivers into the sea.

Glancing at the handsome hotel over there, that looks so well-built and secure, it is difficult to realize that every yard of the Earth's surface is rising or sinking and that, even were they otherwise preserved, every building in the World would in time be laid

flat by that movement, which would cover them with water and bury them miles deep. That in future ages the present land will disappear, and new continents will rise from ocean depths.

It is difficult to believe that the Earth's crust is but a frail, brittle shell, containing gases under such pressures that they behave like solids, that it is continually heaving, straining, cracking, bulging and sinking in, and may at any moment shudder with frightful convulsions occurring no one knows where. That in the solid crust a tidal earth wave forms rolling round it in the path of the sun.

It is difficult to realize that everything we see, organic and inorganic—the land, the sea, the very air we breathe—the whole solar system, was once a fiery nebula, and that to such a nebula it will again return. That the Earth is spinning on its axis at an equatorial speed of a thousand miles an hour, and racing round the Sun through space at over a thousand miles a minute. That, but for a delicate balancing of all these forces, the Earth might instantly be disintegrated and scattered forth as dust in space. That our mighty World, measuring 25,000 miles round, is only one of countless millions, and but a speck in the Universe.

In the peaceful quietude of our surroundings, these thoughts impress us, but more impressive still is it to contemplate the end.

The World will not last for ever. In the foregoing pages we have glimpsed the past and the present.

Looking forward, let us now endeavour to picture the end, and how it may be brought about.

In an earlier chapter reference was made to dark bodies, once suns, that sometimes collide. It is not known how near one of these may be to our solar system, although astronomers would detect its approach many years before a collision could occur. If this should be the premature fate of the World, year by year the influence of the dark, approaching mass would make itself felt more and more, until at length it would appear, like a star, by the reflected light of the Sun.

Astronomers would foretell when it would become visible, and at the appointed time, the eyes of terror-stricken nations would strain at the approaching cause of their impending doom.

The tides of the sea would rise and recede to unprecedented heights and distances; the moon would waver and err in its revolution; frightful earthquakes and volcanic eruptions would shake the Earth through and through.

Finally, dragged from its orbit, the World would be drawn into line between the two principal actors in the terrible drama, where, disrupted—torn or smashed to fragments—its remains would scatter in a fearful chaos of fire and destruction through which the stranger would make its way to the Sun. Then, with a mighty conflagration, a vast nebula would spread out into space.

That is one possibility, although the precise result

would largely depend upon the mass of the unwelcome visitor. Again, one or more of the outer planets, according to their positions, might be the first to receive attention and to suffer eclipse : for instance, Neptune, entering upon a certain arc of his orbit at a critical time, might be arrested in his course and disappear several years before the destruction of the World could take place.

An end-on collision, however, is not the only risk we run. Those who attempt to fathom the mysteries of the Universe, are led to the conclusion that, much as a planet and its attendant moons, each describing its own small orbit, circle round the Sun, so every solar system describes an almost inconceivably immense orbit in space. In such case, one system might encounter another at any angle, so that, instead of an end-on collision, there might be a glancing one. Indeed, without a collision at all (in the ordinary sense of the word) if one system passed near enough to another, the planets of either or both might be dragged from their orbital planes and mingle in a wild chaos of colliding worlds.

If some such catastrophe does not happen first, the whole solar system will gradually die, and it is perhaps some consolation that reasoning prompts the belief that long before such a disaster is likely to occur men will have ceased to multiply, and animals, plants and all living things will have died out as the Earth slowly becomes uninhabitable.

Man's dominion over the lower orders of life is but

a phase in the natural sequence of events. Just as, before his advent, other creatures, long since extinct, held sway on Earth, so the time will come when the human race will die out to make way for other forms of life, and it is a fall for man's pride, as "lord of Creation," that there is good reason for supposing that he will give way, not to higher, but to the lowest and, to him, the most repulsive, types. How precarious his hold of the reins is, even now, may be gauged from a few simple considerations.

The first attempt to construct the Panama Canal was utterly foiled by a species of mosquito whose poisonous injections accounted for the deaths of 22,000 workers. Many years later, when Americans renewed the operations, elaborate experiments and precautions, the cost of which amounted to no less than 5 per cent of that of the canal, had to be undertaken to combat the ravages of this little insect, which for many years had defied the human invader and held up the greatest engineering feat ever attempted by man. Suppose now that Nature, in a capricious mood, acclimatized these poisonous pests to colder regions, and permitted them to multiply at such a rate that they could not be held in check ?

Ask any soldier who fought at Gallipoli during the Great War to relate his experience of flies, and imagine such conditions to become universal !

From time immemorial locust swarms in certain countries have been responsible for local famines : picture the whole World exposed to their ravages !

More insidious, if less ostentatious, in their methods of working and the damage they wreak, are the various wheat and other grain pests.

The menace of the rat is already far more serious than most people suppose. Observations of the habits and courage of these rodents lead one irresistibly to the conclusion that, were they to multiply at several times their present rate, from being a scourge they would become a veritable terror to mankind.

A combination of such possibilities realized would spell famine, starvation and pestilence; and the germs of disease would complete the extermination of the human race—notwithstanding the vaunted triumphs of so-called medical science.

As the World revolves, the tidal earth wave sets up great friction and stresses as it passes round the crust, acting as a brake, lightly but continuously applied, gradually slowing the speed of rotation and lengthening the days. The time will come when the seasons will end, and when the World will rotate on its axis but once during its revolution round the Sun. Time will be meaningless then, for the Sun will never rise or set, and one half of the World's surface will always face it, just as only one side of the Moon is presented towards the Earth to-day. The other side will be in perpetual darkness, frozen like the polar regions. If any life remain, it will only be possible in an intermediate zone, for beneath the scorching Sun, vegetation will wither, and from the parched land and tepid seas hot air will rise and carry moisture

to the dark side, where it will be frozen and deposited in mountains of ice.

It is interesting to speculate on events when the World has performed its last diurnal rotation and begins a pendulum-like swing on its axis like that of Mercury. The tidal earth wave will then roll back and forth, and one may picture volcanic eruptions and earthquakes, transforming the whole face of the Earth until its crust has accommodated itself to the new condition.

As the pendulum swing continues, the attraction of the Sun will drag upwards the portion of the crust facing it, land masses will rise to great heights, ringed round by icefields fringing the sunlit expanse, and on those last mountains water vapour will condense as ice and snow. Finally, the pendulum swing will cease, and our lifeless, ice-bound World will revolve in its orbit, one side vacantly facing the Sun.

As the ages pass, the Sun's heat will dissipate, the Sun itself will become a solid body, cold and darkness will prevail, and, its purpose accomplished, the dead solar system will silently pursue its ghostly career, until it encounters another. Then the final crash will come, and a new and glorious nebula will arise to commence a fresh cycle of stupendous operations in space. That is what astronomers believe that they have seen take place in the heavens, and what astronomers on other spheres may witness when our solar system is destroyed.

It is an awe-inspiring reflection that such utter

destruction should be the end of our Wonderful World: that man and all his works and treasured records must irretrievably perish. Yet it is a grand thought, too. For what are Man's records? Are they not one long story of sin against the Divine Will: of war and bloodshed: of selfishness and avarice: of hypocrisy and injustice masquerading in the robes of state and law? The agony of the oppressed and slain calls for the destruction of such records in a World which God made beautiful, and in which miraculous provision was made for all to benefit alike.

The records of the beauties and miracles of Nature, patiently pieced together by scientists who dimly perceive and love them, must perish too, but that matters not, for the miracles themselves will remain for ever, to be discovered again and again by the scientists of future worlds.

Well may we pause, and, in contemplation of such mysteries, exclaim "Quo vadis?"

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